CONTRIBUTION TO THE SEROLOGY OF LEPROSY

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The serological investigations on leprosy so far have mainly been limited to the Wassermann reaction, and the frequency of positive results has been corroborated by many authors.

Although the high percentage of lepers that give positive Wassermann reaction seems to indicate that the infection by the lepra bacillus itself is capable of producing such physico-chemical changes in the blood as to give positive results, yet the possibility remains that some lepers may be and undoubtedly are afflicted with syphilis.

Recently, Goodpasture[2] reported the results of examinations of lepers by the complement-fixation method, using tuberculin as antigen. He found the serum of lepers to give inhibition of hæmolysis to a variable degree and claims that the inhibition of hæmolysis gradually diminished in lepers under chaulmoogra treatment. The high incidence of tuberculosis in lepers is known, and there is experimental evidence on hand to consider the beneficial therapeutic influence of chaulmoogra treatment upon tuberculous infection. It stands to reason, therefore, that neither the Wassermann reaction nor the tuberculin com-plement-fixation method could serve as a guide in detecting cases of leprosy in the stage when definite clinical manifesta-tions are absent and bacteriologic diagnosis leaves us in the lurch.

[1] Member, Philippine Leprosy Research Board.

[2] Goodpasture, E. W., Philip. Journ. Sci. 22 (1923) 425.

In the absence of a specific reaction in leprosy, and considering the fact that the serum reactions recommended for diagnosis of syphilis, such as the precipitation reactions, appear simultaneously with the Wassermann reaction, we decided to probe the behavior in leprosy of a reaction which is not concomitant with the Wassermann or other serum reaction; that is, the globulin-precipitation reaction. This test, recommended by Klausner for diagnostic purposes, appears positive in the early stage of syphilis before the Wassermann reaction becomes positive and decreases gradually as the Wassermann reaction increases in strength. The nature of this reaction is believed to be a precipitation of globulin out of fresh patient's serum on dilution with distilled water. Upon standing or inactivation the serum loses the property of precipitation.

The technic, as employed in our tests, is very simple. A sufficient amount of blood was withdrawn from the cubital vein of the patient by means of a sterile syringe and placed in a test tube wetted with normal salt solution. As soon as the serum separated, it was pipetted off and placed in two narrow test tubes, 0.2 cubic centimeter each.

Distilled water [3] (0.6 cubic centimeter per tube) was then added carefully to avoid mixing the water with the serum. This was done by means of Wright's pipettes which were marked to contain 0.2 cubic centimeter and 0.6 cubic centimeter, respectively. One test tube was allowed to remain undisturbed, but the other was shaken thoroughly to mix the serum and the distilled water. Special care was taken that all of the sera tested were perfectly clear, and the test was performed not later than five hours after the blood was taken from thé patient.

The test tubes were allowed to stand at room temperature (average 27° to 28° C.) for at least two hours, when a preliminary reading was made. They were then placed in the refrigerator and read next morning. Positive reaction was discernible as a distinct ring at the surface of contact between the serum and the distilled water, while a diffuse cloudiness was perceptible in the tubes in which the serum and the distilled water were mixed. Upon final reading there was a distinct sediment at the bottom of the tube that showed a ring upon first reading. The sediment in the test tube containing serum

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[3] The reaction of the distilled water used in these experiments averaged PH=6.6, or slightly less than—0.1 per cent phenolphthalein.

and distilled water thoroughly mixed was much more volumi-
nous. This sediment, consisting of distinct flakes, was taken
as a positive reaction and not the diffuse opalescence and the
hazy ring; diffuse opalescence occurs in many human sera upon
dilution with distilled water.

Rather than survey a long series of lepers, we selected
limited groups for examination in order to gain information
as to the behavior of the reaction in question in various stages
and forms of leprosy. The duration of the disease is given
as stated by the patients themselves and a liberal limit of error
should be allowed in considering these data, because even a
fairly intelligent patient may be unaware for a long time of
the existence of the disease, as the initial symptoms are not
very definite. [4]

The first group consisted of untreated bacteriologically pos-
itive and negative cases; the second group, treated bacterio-
logically positive and negative cases; the third group, treated
microscopically negative anæsthetic cases; the fourth group,
microscopically and clinically negative, cured lepers; the fifth,
healthy nonlepers.

It can be seen from the results of these tests (Tables 1, 2,
3, 4, and 5) that all forms of leprosy, treated and untreated
cases, cutaneous early and advanced cases, bacteriologically
negative anæsthetic cases, as well as presumably cured lepers,
gave positive results. Furthermore, it is evident that the in-
tensity of the reaction is not dependent on the duration of the
disease, although there seems to be some relation between the
intensity of the reaction and the extent of the cutaneous lesions.
In cured cases the reaction, although positive, was less pro-
nounced than in the active cases.

A method and technic are given here of a serologic reaction
that gave positive results in all cases of leprosy examined.
Macular, nodular, anæsthetic, and mixed forms were tested, as
well as cured lepers. The Wassermann test was performed on
all of these cases, including twelve healthy nonlepers. In the
healthy nonlepers the globulin-precipitation test was negative.
The Wassermann test was positive in about 35 per cent of the
lepers examined, while the globulin-precipitation test was positive
in 100 per cent. One of the healthy nonlepers gave a positive
Wassermann reaction (latent syphilis), becoming negative

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[4] Cf. Gomez, L., The question of the initial lesion of leprosy, Journ.
P. I. Med. Assoc. **3** (1923) 227–229.

after antisyphilitic treatment. The quantitative differences in the results of the tests, as indicated in Tables 1 to 5 by the number of plus signs, refer to the amount of precipitate that formed overnight with sera tested simultaneously. No control was used to compare with the quantitative differences in the strength of the reaction.

In order to establish a uniform and definite standard for gauging the strength of the reaction, we adopted the dilution method in our experiments. In a series of narrow test tubes a constant amount of fresh serum (0.2 cubic centimeter) was added to increasing amounts of distilled water, so that final dilutions resulted in the proportions 1 : 1, 1 : 2, 1 : 3, 1 : 4, and 1 : 5.

A number of healthy individuals, lepers, apparently cured lepers, and nonlepers suffering with tuberculosis, syphilis, yaws, and beriberi were subjected to the test. The results are evident from Tables 6, 7, 8, and 9.

If we examine these tables and draw a line through the 1 : 3 dilution column we can see that none of the plus signs cross this line in the tests that were performed with sera of healthy nonlepers. However, the sera obtained from cured lepers show a tendency, even though slight, to approach the normal line, particularly if we consider the 1 : 3 dilution column.

On the other hand, the results with sera from certain non-leprous patients deviate from the findings made in healthy persons in as much as positive precipitation occurred in dilutions lower than 1 : 4. These sera were obtained from cases of early and recrudescent syphilis, beriberi, and yaws.

The experiments given in Table 10 were arranged in order to obtain information as to the nature of the reaction. The precipitate that forms with positive sera behaves in many respects like globulin. It is insoluble in distilled water but soluble in normal salt solution and in concentrated solution of sodium chloride.

Further information was sought as to the influence temperature has upon the reaction. It has been noticed that the sera tabulated in Tables 1 to 5, when retested after inactivation for thirty minutes at 56° C., gave negative results, with the exception of a few strongly reacting sera, some of which showed a faint precipitate after inactivation. It shows that the inactivation decreased the reactivity of the sera.

The influence of temperature on the course of the reaction proper is evident from the results of experiments tabulated in

Tables 10 and 11. It shows that the precipitation is promoted by lower temperature and does not occur at higher temperature in every case. The serum, however, can be preserved at low temperature for at least twenty-four hours without losing its reactivity completely.

In the experiment given in Table 10 there was no difference in the amount and character of the precipitate, whether the serum-distilled water mixture was incubated at 37° C., at room temperature (average, 27° to 28° C.) preliminary to storing in the ice chest (9° C.), or placed immediately in the ice chest. On the other hand, the serum-water mixture allowed to stand at room temperature or at 37° C. did not precipitate at all in some cases. Fresh sera allowed to stand in the ice chest over-night and retested twenty-four hours later gave positive re-sults, one of them showing a slight decrease in titer (Table 11).

The condition found in the sera of lepers and certain other patients may be conceived as an upset balance between salts and globulin, possibly euglobulin. Therefore, it has not the significance of a strictly specific immune reaction but, owing to its apparent constancy in leprosy, may prove to be of help as an adjuvant test. It is, moreover, a promising hint to those who may consider a thorough investigation of blood chemistry in leprosy.

Thanks are due to the chief of San Lazaro Hospital and to the staff of the leper department for their courtesy in supply-ing the necessary material.

The following symbols are used in Tables 1 to 11: —, nega-tive; +, positive; ±, faint reaction; O, not examined.

TABLE 1.—*Results of globulin-precipitation and Wassermann tests in un-treated microscopically positive and negative cases.*

[Dilution, 1 : 3 water.]

Name.	Age.	Duration of sickness.	Globulin test.		Wasser-mann reaction.	Remarks.
			Ring.	Precipi-tate.		
	Yrs.	*Yrs. mos.*				
F. C_____	16	0 1	+	+	±	Macular; positive.
J. A_____	60	7 0	+++	+++	—	Macular; tubercular; positive.
E. M_____	18	0 5	++	++	—	Do.
R. U_____	22	2 0	+	+	—	Macular; positive.
B. D_____	48	2 0	+	+	—	Paresthesia; t i q u e convulsive; nega-tive.

TABLE 2.—*Results of globulin-precipitation and Wassermann tests in cutaneous form of leprosy in treated microscopically positive and negative cases.*

[Dilution, 1 : 3 water.]

Name.	Duration of sickness.		Globulin test.		Wasser-mann reaction.	Remarks.
			Ring.	Precipi-tate.		
	Yrs.	*mos.*				
B. T	1	6	±	±	—	Tubercular; positive.
A. S	12	4	±	+	±	Do.
G	1	6	+	++	±	Macular; tubercular; positive.
E. B	1	6	+	+	—	Tubercular; positive.
F. V	1	2	++	++	—	Macular; tubercular; positive.
R. M	2	8	+	++	+	Mixed; positive.
C. M	7	6	+	++	±	Do.
J. M	3	0	±	+	—	Macular; positive.
S. C	1	6	±	+	—	Macular; tubercular; positive.
A. V	2	6	+	+++	+	Do.
J. R	0	8	+	++	±	Do.
P. E	4		++	++	—	Macular; negative.
J. M	0	9	±	+	—	Do.
R. R	0	10	+	+	—	Do.

TABLE 3.—*Results of globulin-precipitation and Wassermann tests in treated microscopically negative anæsthetic cases of leprosy.*

[Dilution, 1 : 3 water.]

Name.	Age.	Duration of sickness.		Globulin test.		Wassermann reaction.
				Ring.	Precipi-tate.	
	Yrs.	*Yrs.*	*mos.*			
B. L	15	3	4	++	++	—
M. R	15	2	3	++	++	—
P. C	55	2	0	++	++	++++
P. E	30	16	0	+	+	—
F. G	23	3	0	++	++	—

TABLE 4.—*Results of globulin-precipitation and Wassermann tests in micro-scopically and clinically negative presumably cured lepers.*

[Dilution, 1 : 3 water.]

Name.	Age.	Duration of sickness.		Negative.		Globulin test.		Wasser-mann reaction.
						Ring.	Precipi-tate.	
	Yrs.	*Yrs.*	*mos.*	*Yrs.*	*mos.*			
I. L _____	15	(?)		1	0	—	±	±
J. F _____	21	7	0	3	0	—	±	±
A. R. F _____	32	1	6	0	6	+	+	—
P. S _____	34	2	0	0	7	+	+	—
A. M _____	31	2	0	0	7	+	+	±

TABLE 5.—*Results of globulin-precipitation and Wassermann tests in normal nonlepers.*

[Dilution, 1 : 3 water.]

Name.	Age.	Globulin test.		Wasser-mann reaction.	Remarks.
		Ring.	Precipi-tate.		
	Yrs.				
C. C _____	22	—	—	—	
F. M _____	22	—	—	—	
V. B _____	18	—	—	—	
F. D _____	18	—	—	—	
F. R _____	19	—	—	—	
P. C _____	23	—	—	—	
F. C _____	24	—	—	++++	Latent syphilis.
A. C _____	21	—	—	—	
B. A _____	21	—	—	—	
L. D _____	17	—	—	—	
A. I _____	(?)	—	—	—	
J. E _____	18	—	—	—	

TABLE 6.—*Results of titration of fresh sera from cured lepers.*

[0.2 cubic centimeter of serum mixed with increasing amount of water.]

Name.	Age.	Duration of sick-ness.		Negative.		Globulin precipitation, water in cubic centi-meters.				Wasser-mann reaction.
						0.4	0.6	0.8	1.0	
	Yrs.	*Yrs.*	*mos.*	*Yrs.*	*mos.*					
P. R _____	47	(?)		4	0	—	±	+	+	—
C. M _____	20	2	6	1	0	±	+	+	+	—
E. E _____	45	8	0	4	0	±	+	+	+	—
M. S _____	53	11	0	8	0	±	+	+	+	—
J. C _____	48	5	0	1	6	—	±	+	+	—
A. G _____	33	3	0	2	0	—	±	+	+	—

TABLE 7.—*Results of titration of fresh sera from active cases.*

[0.2 cubic centimeter of serum mixed with increasing amount of water.]

Name.	Globulin precipitation, water in cubic centimeters.			
	0.4	0.6	0.8	1.0
M. S _____	—	+	+	+
F. R _____	±	+	+	+
S. C _____	+	+	+	+
J. S _____	±	+	+	+
B. P _____	—	+	+	+

TABLE 8.—*Results of titration of fresh sera from healthy nonlepers.*

[0.2 cubic centimeter of serum mixed with increasing amount of water.]

Name.	Globulin precipitation, water in cubic centimeters.			
	0.4	0.6	0.8	1.0
R. R _____	—	—	±	+
D. P. A _____	—	—	—	±
D. J. B _____	—	—	—	—
M. T _____	—	—	—	—
C. C _____	—	—	—	—
V. B _____	—	—	+	+
F. M _____	—	—	—	—

TABLE 9.—*Results of titration of fresh sera from nonleprous patients.*

[0.2 cubic centimeter of serum mixed with increasing amount of water.]

Name.	Globulin precipitation, water in cubic centimeters.				Wassermann reaction.	Remarks.
	0.4	0.6	0.8	1.0		
R. M _____	—	±	+	+	—	Beriberi.
M. R _____	±	+	+	+	_____	Yaws, latent.
J. A _____	—	—	O	O	_____	Tubercular, afebrile.
Cyr _____	—	—	+	+	_____	Do.
G. S _____	—	—	O	O	+++	Syphilis, latent.
M. E _____	—	+	+	+	++++	Syphilis, early.
B. B _____	—	—	±	+	++	Syphilis, latent.
R. T _____	—	±	+	+	+++	Do.
F. D _____	—	±	+	+	+	Suspected syphilis.

TABLE 10.—*Influence of temperature upon the globulin precipitation test.*

Amount of fresh serum.	Incubated at—			Result with sera of—			
	Room temperature.	37°. C.	Ice box, 9° C.	S. R.	S. C.	J. S.	B. P.
cc.	*Hrs.*	*Hrs.*	*Hrs.*				
0.2_____	2	0	12	+	+	+	+
0.2_____	0	2	12	+	O	O	O
0.2_____	0	18	0	—	+	—	—
0.2_____	18	0	0	—	+	+	+
0.2_____	0	0	18	+	+	+	+

TABLE 11.—*Keeping quality of fresh sera at low temperature.*

FRESH SERUM.

Name.	Form of leprosy.	Duration of sickness.	Dilutions.					
			1:1	1:2	1:3	1:4	1:5	1:6
		Yrs.						
M. S_____	Mixed_____	10	—	—	+	+	+	+
F. R_____	_____do_____	1	—	±	+	+	+	+

SERUM 24 HOURS OLD, 9° C.

M. S_____	Mixed_____	10	—	—	+	+	+	+
F. R_____	_____do_____	1	—	—	+	+	+	+

TERTIARY PALEOGEOGRAPHY OF THE PHILIPPINES

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FOUR PLATES AND TWELVE TEXT FIGURES

INTRODUCTION

Geology and that particular phase of biology known as bio-geography, which deals with the distribution of life forms, are connected through paleogeography. Paleogeography seeks to delimit the former shore lines of islands and continents and to interpret, by indirect evidence, information concerning the topography of these land masses. The changes that cause the shifting patterns, first uniting and then disconnecting portions of land on the outer edge of the continental platforms, vastly influenced life upon land in such regions. These changes during the Tertiary in the Philippines are very notable and, in order to grasp the fundamentals of the distribution of life in the Philippines, some idea of the Philippine Islands of the past is necessary. May the broad outlines here sketched prove useful to workers in both geology and biology.

PALEOGEOGRAPHY

The geological record in the Philippines is unusually fragmentary when comparison is made with the neighboring island Borneo. As yet no Cretaceous, Eocene, or Oligocene rocks have been recognized in the Philippines. Only cherts of questionable Jurassic age, Miocene sandstones, limestones and shales, Pliocene coralline limestone and rocks largely composed of detrital material from coral reefs and from igneous flows of andesite or basalt, and Pleistocene coralline limestone and sands record the history of ancient life in the Philippines.

THE PHILIPPINES DURING EARLY TERTIARY TIME

The lack of any early Tertiary sedimentary record leaves this important portion of the time in which modern life had its beginning largely blank. Our information concerning conditions previous to the Miocene depends upon inferences derived from a

11

study of the character of Miocene sediments and from certain indirect paleontological evidence concerning Formosan botanical affinities. The sedimentary rocks of Vigo-Miocene age, which are characterized by the presence of the finger posts of the East Indian Miocene, *Vicarya callosa* Jenkins and various species of *Lepidocyclina* and associated Foraminifera at various horizons, contain detrital material which has obviously been obtained through erosion of the basement complex of cherts, schists, serpentine, and diorite. At places, the materials contained in the Vigo sandstone is very coarse, and conglomerates occur locally in Bondoc Peninsula, southern Luzon, and on a great scale in northwestern Leyte, east of Tabubunga Barrio, where they in part closely resemble characteristic desert fanglomerates.

Again, in Panay, the thick lower portion of this group is composed of massive conglomerates, evidently derived from a source close at hand. Coarse materials also compose portions of the Vigo strata west of Baguio and in Cagayan Valley, northern Luzon, and in Mindanao as well. Such materials could not have been transported great distances, thus evidencing a land mass composed of the rocks of the basement complex. During early Vigo time the sedimentary record of Formosa is in part the same as that of the Philippines. Eocene has been recently discovered in the so-called clay slate strata of this island. Cretaceous has not been reported, but one must remember that this large island, like the Philippines, has not been studied in detail. Paleozoic rocks occur in the central part of Formosa, according to Dr. S. Nakamura, of the Imperial University of Kyoto. As far as our present knowledge goes, all of Tertiary time previous to the Vigo-Miocene may be recorded by the unconformity between the Vigo and the basement-complex rocks. In other words, Formosa and the Philippines may have been a united land mass (fig. 1).

The other evidence pointing in the same direction is supplied by Elmer D. Merrill and by Warren D. Smith.[1] At Sagada, in northern Luzon, at an elevation of 1,500 meters, Father Staunton discovered a fossil flora locality, and Doctor Smith collected the fossils which were determined by Elmer D. Merrill. Among them were characteristic dipterocarps at present living only at sea level or at elevations below 600 meters. Now, this flora is stratigraphically connected with Malumbang-Pliocene coralline

[1] Smith, W. D., Notes on a geologic reconnaissance of Mountain Province, Luzon, P. I., Philip. Journ. Sci. § A **10** (1915) 195–197.
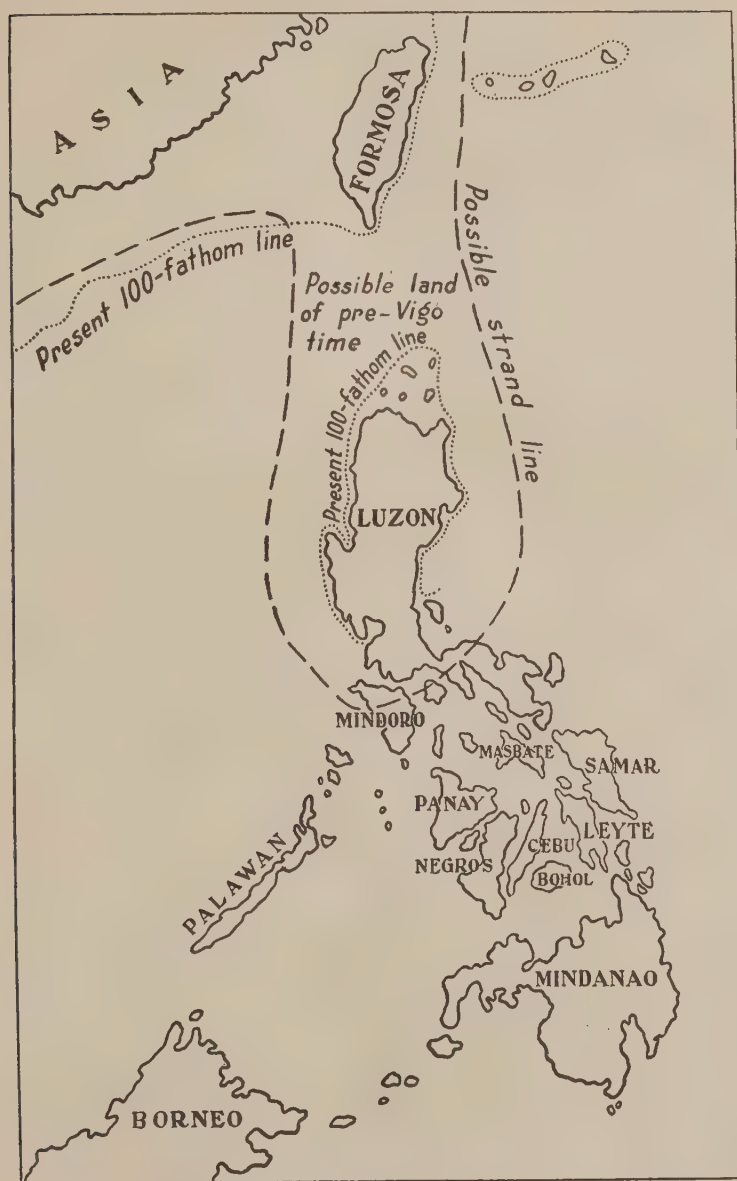
FIG. 1. The Philippine Islands, showing hypothetic connections during pre-Vigo time.

limestone at this place. The point of this matter is that no dipterocarps occur in the Formosan flora of to-day. According to Merrill, the climate and soil are not unsuitable in Formosa, and he can see no reason for their absence except its long separation from the Philippines. The absence of the dipterocarps from Formosa leads, then, to the conclusion that that island was not connected with Luzon during the Pliocene. Unfortunately, no decisive paleobotanical evidence from Formosa is at hand; but the study of the distribution of marine sediments of Vigo age, both in Formosa and in the Batanes and Luzon, indicates with great clearness that much of the present site of both Formosa and northern Luzon, as well as the intervening Batanes region, was covered by waters of the Vigo-Miocene sea. Dr. Albert W. C. T. Herre's recent investigations upon the fresh-water fishes of the Philippines shows that no forms having affinities with Formosan fresh-water fishes are known. All Philippine true fresh-water fishes are allied to Bornean forms. This evidence is in entire accord with the known geological data. Hence, a connection between Luzon and Formosa at this stage is highly improbable.

At various places erosional contacts between the Vigo and the basement complex indicate that a great period of subaërial erosion preceded the deposition of marine Vigo-Miocene. At this stage it is highly probable that Formosa and northern Luzon were firmly connected, and it is even probable that the plants common to these two islands spread southward from Formosa at this time. Definite evidence of the precise stage at which this floral occupation occurred is lacking, but it is the writer's opinion that it was during the interval between the Oligocene and the Miocene; that is, Ep-Oligocene time or early Miocene. This opinion is based upon the probable rate of evolution of plants. It seems highly improbable that about forty present-day plants common to Formosa and northern Luzon could have persisted in both Formosa and Luzon for a greater period without specific change. This idea is tentatively set forth by the accompanying map of pre-Vigo time (fig. 1). Just how far to the south this probable pre-Vigo land mass extended is problematical, as the present-day, high-altitude flora does not persist farther south than the present high mountains of northern Luzon, and other guides are lacking, as probably all of this southern area was under the sea during a portion of the geologic time after the beginning of the Vigo.

THE PHILIPPINES DURING VIGO-MIOCENE TIME

As indicated above, the Vigo group of Miocene age, which is characterized faunally by the presence of *Lepidocyclina* and the gastropod *Vicarya callosa,* was deposited unconformably upon the basement-complex rocks. As was noted above, moreover, in certain localities the Vigo sedimentaries are conglomerates and coarse-grained sandstones derived from the basement-complex rocks, in marked contrast with great thicknesses of shale and limestone which indicate accumulation in deeper waters. When the distribution of these two types of rock shall have been studied some conclusions will be possible. The basal member of the Vigo group in Leyte near Tabubunga on the northwestern coast is a thick fanglomerate which very evidently was deposited either as land-laid material or close to the shore, since some of the bowlders are more than a meter thick. The prevailing sediments in Cebu, on the other hand, probably not very far above the base, are coal seams associated with *Lepidocyclina* limestones which are in turn overlain by fine-grained shales. While the coal may be regarded as lagoon or shore-marsh deposits, the *Lepidocyclina* limestone indicates deposition in water decidedly offshore; that is, not strictly littoral deposits. Samar, likewise, is characterized on the whole by shales and *Lepidocyclina* limestone. *Lepidocyclina* limestone is found above the coal on Batan Island off the east coast of Camarines Peninsula. West of Camarines Peninsula is Bondoc Peninsula, the type locality of the Vigo group. Upon this peninsula the Vigo is, in general, represented by shales, sediments probably deposited in the deeper waters of a Vigo inland sea. Farther to the north, on Polillo Island, coal of commercial value is reported by W. D. Smith, which fact indicates a shore-line condition. The connection between this island and the central highland of northern Luzon is probably broken by relatively recent movements along the northern end of the Taal fault which now marks the continental shelf along the steep eastern coast of northern Luzon. This great fault extends from the west side of Palawan, at sea, northeasterly across central Luzon. In all probability, Vigo sediments have been dropped downward upon the eastern side of the Taal fault, while the older basement-complex rocks have been upthrust to form the steep-cliffed, east-coast mountains, the wild Sierra Madre Range. The Vigo sedimentaries of Cagayan Valley are in general coarse-grained sandstones and lignites and apparently represent shallow-water deposition in a marked geosynclinal trough which was

bordered by land on either side. On the northwest coast of
Luzon the great section of the Vigo group exposed along the
Naguilian Road west of Baguio evidences littoral deposition.

Now, this distribution of sediments as briefly outlined above
indicates that an elongate Palawan-like island existed which
stretched from the eastern coast of Mindanao through central
Leyte, through Camarines Peninsula, across the embayment on
the eastern side of Polillo, northward on the east side of northern
Luzon (fig. 2). In all probability, during Vigo time there was
a good-sized island mass in Abra Province and in western Ka-
linga and Apayao Subprovinces of the Mountain Province. The
great amount of coarse sediments exposed along the Naguilian
Road west of Baguio, Benguet Subprovince, indicates that land
was close at hand. Whether in addition to this smaller island
through north-central Luzon there was another, 64 to 80 kilo-
meters west of northern Luzon, in the China Sea site of to-day,
is hypothetical; but the great thickness of the Vigo group and
the coarse character of these sediments indicate a neighboring
land mass of larger size than the narrow island or peninsula
which separated the Cagayan Vigo embayment from the basin
of deposition west of Baguio. The ocean contours delimiting the
west side of northern Luzon might well be interpreted as indicat-
ing a continuation of the great Formosa fault which delimits
this island on its eastern side, and movements along such a fault
may have carried this western island of Vigo time beneath the
sea. The great amount of coarse sediments described by Abella
in the basal Tertiary beds in Iloilo Province, Panay, indicates
that the material of Vigo-Miocene age was derived from a con-
siderable land mass entirely or in part to the west of Panay
Island of to-day. A study of the orientation of Tablas Island
and the western coast of Panay lends some support to this hy-
pothesis, and it is possible that such an older land mass is now
covered by the waters of Cuyo East Pass. In other words, a
dropped block is now present west of Panay. Connections to the
south from Mindanao to Celebes during Vigo-Miocene are en-
tirely probable and, from the biologic evidence, Celebes may have
been connected either directly or indirectly by a stepping-stone
bridge or a more solid structure with this elongate north-stretch-
ing island. Information concerning paleogeographic details of
the Philippine Archipelago during the Vigo-Miocene are dis-
tinctly hazy, but we may at least conclude from all the evidence
at hand that an archipelagic condition prevailed during those
times.

FIG. 2. Probable islands in the Philippine area during Vigo-Miocene time.

SOME POSSIBLE PLIOCENE PHILIPPINE ISLANDS

As incidentally indicated in this discussion of the Vigo-Miocene the sediments were very evidently derived from erosion of an older land mass composed of diorites, slates, schists, and cherts; but a study of the Pliocene beds as exposed in the Philippines indicates that the dominant process during this stage was the accumulation of organic sediments and volcanics. The writer recognizes that this is not wholly true, as Schenck and Moody have demonstrated the presence of bowlders of *Lepidocyclina* limestone of Vigo-Miocene age in Pliocene strata of probable Malumbang-Pliocene age. Such evidence indicates that the Vigo sediments have been consolidated, faulted, and eroded in part to form the sediments of the Pliocene sea. There is a remarkably small amount of quartzitic or dioritic rock fragments in the sandstones of Pliocene age. The abundance of andesitic bowlders and fragments of coral rocks containing species closely related to or identical with those living in the Philippine waters of the present day, is a notable character in the Pliocene sediments about Baguio, Mountain Province, northern Luzon. However, Smith reports much sandstone of upper Pliocene age associated with coralline limestone in his Banisilan beds in the region north of Cotabato River. In most of the larger islands of the Philippine Archipelago, coralline limestone of Pliocene age is common, and the corals composing them are typical of the fringing reefs now bordering the shore line of the islands of this group to-day. It is well known that these reef corals are limited to waters varying from sea level to a maximum of about 70 meters in depth. Such widespread occurrence of coralline limestone, which indicates such shallow deposition, evidences again an archipelagic condition of the Philippines during their deposition. The location of land masses during this stage is indefinite and vague. A portion of the present site of Samar was probably land during Malumbang time, as the Malumbang on this island is derived directly through erosion from previously formed *Lepidocyclina* limestone of Vigo-Miocene age. The present site of Agusan Valley in Mindanao was occupied by the shallow waters of a Pliocene sea, as is indicated by the presence of fossils at several points in Agusan, Saug, and Tagum Valleys. These sediments are all of the inshore type, and an island occupying the eastern side of Mindanao of to-day and, possibly, extending several miles farther east of the present shore line, seems probable. A study of Malumbang-Pliocene in the northern peninsula of Leyte and

the southern peninsula of the same island indicates that most of this island was covered by shallow waters at this stage. Most of Bohol is composed of Malumbang-Pliocene limestone, and the presence of the same rock in Cebu is notable. North of Cebu, apparently the entire island of Masbate of to-day was covered by a shallow Pliocene sea, and a striking unconformity on Ticao Island between these rocks and the rocks of the basement complex was found by Dr. A. N. Kryshtafovich. The wide extent of Malumbang limestone in Bondoc Peninsula, Luzon, as indicated by Pratt and Smith, demonstrates that this site was likewise beneath the waters of the sea at this stage. Owing to the great amount of volcanic rock and rocks of the basement complex in Camarines Peninsula, but little is known concerning the presence of marine sediments at this stage; and, although lack of evidence is no adequate proof, it seems to the writer that the Pliocene island of Samar may have extended northward covering a portion of this peninsula. In northern Luzon, however, the evidence is far clearer, and island masses or a single large irregular island covered the present site of northern Luzon. As was indicated briefly in the discussion of the distribution of the dipterocarps above, landlaid tuffs found in Sagada in close association with coralline limestone demonstrate the presence of adjacent land. In Cagayan Valley Doctor Kryshtafovich found a similar fossil dipterocarp flora associated with Malumbang strata, and upon these two bases the presence of a large irregular island or islands in this region has been indicated.

Rocks of Malumbang-Pliocene age occur in Negros and are present in great amount in the central portion of Panay. In southern Mindoro, rocks referred to this age were discovered by Moody and Kryshtafovich. Coralline limestone is reported at a few other places upon Palawan. Such evidence indicates that in the Pliocene a Philippine archipelago existed with, in all probability, the same elongate series of islands or a single irregular island as probably existed in Vigo-Miocene upon the eastern side of this group. Certain other well-recognized island masses existed in northern Luzon, and it is quite probable that a rather large island or islands occupied portions of the present site of Panay and Negros. It is exceedingly important to grasp the significance of this continued insular condition during the Miocene and Pliocene periods and the persistence of the elongate island on the eastern side of the Philippines when the questions of the distribution of plant and animal life are considered (see fig.

FIG. 3. Some probable Pliocene islands of the Philippine area. Shading represents marine
Pliocene rocks.

3). The apparent scarcity of large mammalian remains in the Philippines is possibly a reflection of this persistent insular condition. The possibility that Mindanao was connected through the Sulu bridge with Borneo during the Pliocene is suggested by the reported discovery in northern Mindanao of *Stegodon,* a genus of elephants that was exceedingly common in the Pliocene of India and other portions of Asia. However, there is some doubt concerning the authenticity of this occurrence in Mindanao, and we are unable to assert with positiveness that the Sulu bridge was a stable structure during that time. The wide extent of shallow-water deposits of Pliocene age in the Philippines indicates in all probability that the submarine topography of that period was quite different from the complicated topography of the ocean bottom of the present day.

Other, broader considerations, which will be discussed in connection with the subject of hydrography, indicate that the present sea bottom of the Philippines with the sharp contrast between elevated islands and great deeps, such as the Sulu and Mindanao deeps, has been formed since the Pliocene.

PLEISTOCENE PHILIPPINE ISLANDS

Much of interest to the biologist will be found in the consideration of the distribution of Pleistocene sediments in the Philippines. In the discussion given above, much of the information of interest to geologists and paleontologists is vague and indefinite, but there are certain general conclusions which can be drawn upon the basis of our present knowledge. Our knowledge of the Pleistocene is likewise very fragmentary. Mr. Graham B. Moody, who has made an excellent reconnaissance of Mindanao, outlined some of the complexities that occurred during this period. His statement in a letter concerning Pleistocene conditions is as follows:

Along the north coast of Mindanao between Iligan and Cagayan, there are seven wave-cut terraces in the hills to an estimated elevation of 360 meters. The north edge of Camiguin Island shows excellent benches. There are well-marked, wave-cut benches in the hills south of Cotabato to an estimated elevation of 300 meters. Musuan Volcano, south of Mailag, Bukidnon Subprovince, has a terrace cut practically around it at an elevation of about 400 meters. The hills west of Malaybalay, Bukidnon, exhibit terraces at elevations well over 600 meters, but these may be due to successive flows of lava producing a bench effect. Malitabug River Valley at Banisilan, Cotabato, has five distinct stream terraces on each side, Banisilan being located on the oldest terrace at about 375 meters elevation, while the present elevation of the river is about 200 meters. [See Plate 1, fig. 1.]

A coralline limestone containing many living species of coral, and lying horizontally or only slightly inclined, is widely distributed throughout certain parts of Mindanao and, where in determinable relation with other rocks, always overlies them. This coralline limestone is found on islands in Davao Gulf; in Saug River, Davao Province; at an elevation of about 210 meters on the ridge between Saug and Agusan Rivers; at elevations of 150 meters in tributaries to Agusan River; throughout the floor of Cotabato Valley; and in the hills south of Cotabato at an estimated elevation of 300 meters. This limestone is probably Pleistocene in age.
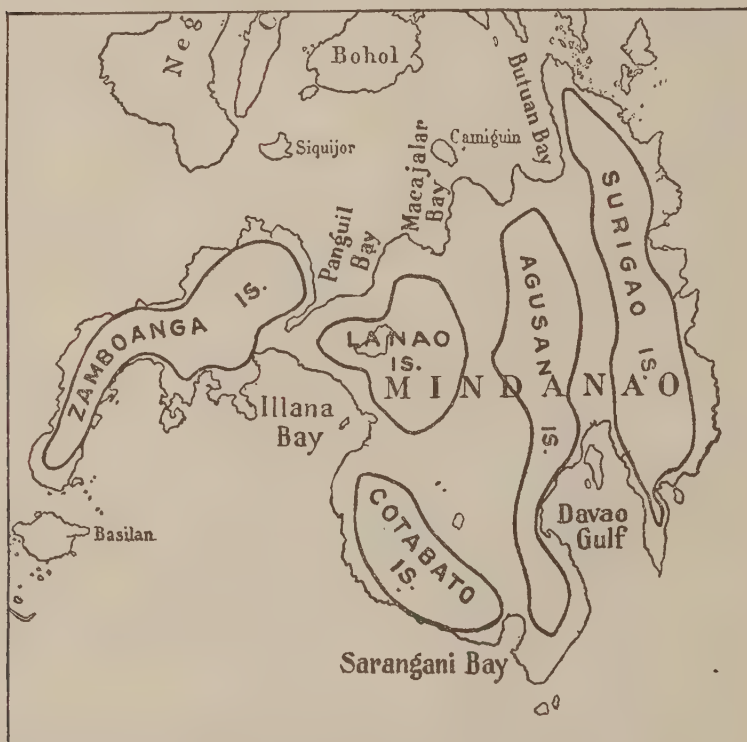
Fig. 4. Mindanao islands during early or middle Pleistocene.

The data noted above suggest that Mindanao was devided into five smaller islands in early Pleistocene time. There were probably water connections as follows: Butuan Bay to Davao Gulf, Macajalar Bay at Cagayan de Misamis through Bukidnon Province to Illana Bay at Cotabato with probably a connection to Sarangani Bay, and from Panguil Bay to Illana Bay. [See fig. 4.] Pulangi River rises in the northeasterly part of Bukidnon Province, flows southerly through the mountains for about seventy-two kilometers, then turns abruptly to the west and debouches

upon the Bukidnon Plain to flow again southerly for about seventy-two kilometers to Kabakan, Cotabato Province, at which point it becomes Cotabato River and meanders westerly through Cotabato Valley to Illana Bay. The course of Pulangi River indicates, as first suggested by Doctor Dickerson, that this river emptied into the Cotabato-Cagayan Strait at about Lumbayo, Bukidnon, in early Pleistocene time. The gulf floor was then elevated to form the Bukidnon Plateau and Pulangi River then intrenched itself in a southerly course, emptying into Cotabato Gulf of later Pleistocene time somewhere near Kabakan. The floor of Cotabato Gulf then slowly emerged to form Cotabato Valley, and Pulangi River found its way westerly to Illana Bay through Cotabato Valley. The other northerly tributaries of Cotabato River; namely Libungan, Malitabug, and Maridagao Rivers exhibit analogous drainage histories. Some of the tributaries of Agusan River north of Talacogan flow in a southerly direction until they meet Agusan River, when the direction of flow changes to north. This suggests that these rivers formed their channels and flowed into the Davao-Butuan Strait in early Pleistocene time and that they still indicate their original drainage although subsequent uplift caused the chief drainage to be to the north. The Post-Pliocene uplift of Mindanao seems to have taken place in about seven well-marked stages and the total elevation has been at least 360 meters.

The accompanying map shows the approximate outlines of the five major Pleistocene islands of Mindanao (Pleistocene-Mindanao) which are for convenience given names. [See fig. 4.] Although this map does not demonstrate clearly the fact, these Pleistocene-Mindanao islands coincide closely with the present topographic high places of Mindanao; the present low places correspond to the early-Pleistocene seas and straits. This division of Mindanao into five major early-Pleistocene islands is based upon the distribution of the Pleistocene coralline limestone and wave-cut terraces and is a tentative separation. Further investigation will probably show that Pleistocene-Mindanao islands Zamboanga, Surigao, and Agusan were really two islands each; but present evidence is not sufficiently definite to subdivide them. Cotabato Island was undoubtedly not a single island, but a group of small islands. It will be noted that the five major Pleistocene-Mindanao islands form an insular group not much dissimilar to the present Visayan group.

Four of the most striking topographic features of Mindanao are: (a) Agusan Valley and its huge swamp, (b) Cotabato Valley and its vast marsh areas, (c) Bukidnon Plateau, and (d) Lake Lanao. These phenomena have been largely affected by post-Pliocene activity. The Agusan swamp is due to sinking along a fault zone, which is still a zone of maximum tectonic activity. Cotabato Valley is the floor of a gulf elevated in post-Pliocene time, with low spots covered with water. Bukidnon Plateau was the northerly extension of Cotabato Gulf and was elevated before the present Cotabato Valley was formed; lava flowed over the northern part of Bukidnon Plateau subsequent to or during its elevation. Lake Lanao, elevation 660 meters, represents the blocking up of a large Pleistocene valley by repeated flows of igneous rock during the period of Pleistocene elevation.

Those familiar with Philippine geology may question the use of a coralline limestone as an horizon marker and they may have good reason for their

doubt. Corals now growing along the shores of the Philippine Islands, corals collected from the Pleistocene limestone, and corals collected from the Malumbang limestone are, so far as is known, generically and specifically the same; this also holds true for the pelecypods and gastropods. If a coralline limestone lies horizontally, or nearly so, it is assigned to the Pleistocene. In some places, for example, the northwest coast of Leyte, horizontal coralline limestone lies across the truncated edge of upturned limestone; here the upper limestone is called Pleistocene and the lower limestone Pliocene (Malumbang). Separation of Pleistocene limestone from Pliocene limestone can be, under present limitations of collected data, only fairly accurate. It is to be hoped that some determinative characteristic of one of these limestones may be worked out.

When one remembers that the Pleistocene period was not simple, but was complicated by an alternation of warm and cold stages, even greater complications were probably present than Mr. Moody's interesting discussion indicates.

North of Mindanao benches, about 120 or 150 meters elevation, are described by several observers in Bohol, Leyte, and Samar. The abundance of coralline limestone and marl and a well-marked marine terrace over the southern half of Bohol indicate that but little of Bohol was above sea level during the Pleistocene. Likewise, very notable terraces are found in the neighboring island Leyte in the northwest peninsula, where they have been studied with some care. These terraces are particularly well exposed in the area immediately south of Rabin Point, the northwest cape of Leyte. Here there are at least four terraces at approximate elevations of 4.5, 30, 60, and 105 to 120 meters above the present sea level. The Pleistocene coralline limestone is apparently thick in this area, and judging from a contact about 6 kilometers south of the point at Daja Bay the unconformity between this Pleistocene coralline limestone and the steep-dipping beds of Vigo age can be well seen in the north headland of Daja Bay. An estimated thickness of coralline limestone based upon these data and the elevations of some of the terraces is between 60 and 90 meters. When one traverses the terraces in the vicinity of Jubay, a small barrio on the west side of this peninsula in the vicinity of Rabin Point, nothing but coralline limestone is seen. The 30-meter and 60-meter terraces appear to persist over the whole southwest side of Leyte. Thus, on the north headland of Tabango Bay, the 60-meter terrace is particularly well pronounced. The 30-meter and 60-meter terraces occur likewise in the vicinity of Palompon and are probably present southeast of Maasin on the peninsula south of Baybay. On this southern

peninsula of Leyte there is marked evidence of a still higher terrace at 120 to 150 meters elevation. The changes in level of the strand line in Pleistocene time thus indicated were probably even more complicated. In certain regions in Leyte there are distinct evidences of recent depressions. In the vicinity of San Isidro and Arevalo Bays on the west side of the northern peninsula excellent proof of depression is presented. Along the trail between Tabango and San Isidro beautiful views of these small bays are seen. The picturesque gateways of these bays, composed of massive, resistant rocks of the Malumbang and Canguinsa formations, are striking features. Near Arevalo Bay these rocks dip west at an angle of 20°. From the divide ridge between Tabango and Arevalo Bays there appears to be a general even surface which truncates the hills at an elevation of about 150 meters, probably an old marine terrace. This surface was developed at or above sea level, as the drainage of the present clearly had an antecedent history which is evidenced by the water gaps of seaward-dipping sandstones and marls and coralline limestone of the Malumbang formation of Putingbato Ridge as well as the tuffaceous member of the Vigo group. Where the rocks traversed by the stream were resistant the former stream valleys were narrow, and the headlands of the bays of the present time were formed in this manner. Such topography and stream development indicate that the first streams were developed upon a broad, nearly level surface, gently sloping to the sea, and that they cut across the country on the surface of a probable Pleistocene age. Successive uplifts of Leyte and the vicinity followed; as a result of this movement, the streams were rejuvenated and they proceeded to cut cañons across the hard resistant rock, the more resistant Malumbang and tuffaceous member bordering the present coast beneath the soft Pleistocene surface, and rapidly widened their cañons in the soft shales of the Vigo group. Later, depressions occurred and the Visayan Sea invaded the land occupying the narrows of the former cañons and portions of the widened valleys within. The streams with their heavy loads of silt, the reef corals, and the mangroves are aiding the land to recover its own. Such events have resulted in the production of the surpassing beauty of Arevalo Bay with its fine ramparts of white limestone and sandstone guarding its entrance and the surrounding grass-covered hills and green-bordered shore of mangroves.

Similar history with similar complications has recently been reported by Schenck.[2] The conditions on the east side of Samar in the vicinity of Taft and Dolores are described by him as follows:

Embayed and irregular shore lines and the drowning of Malinao River are evidences of subsidence in the vicinity of Taft and Dolores. Coral reefs, also, point to subsidence. Fig. 1 [fig. 5 of the present paper] is a profile of the ocean floor east of Taft and shows a gently shelving
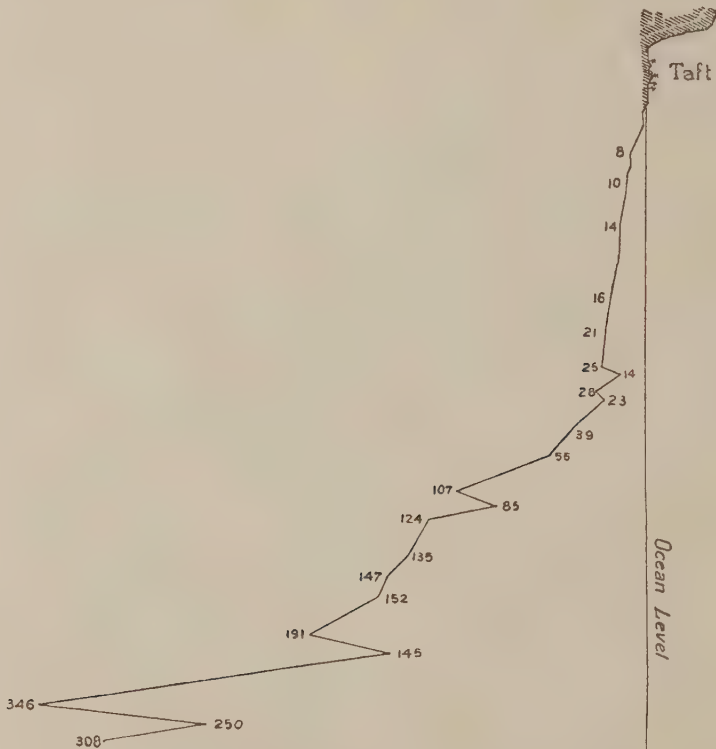

FIG. 5. Taft to the Pacific Ocean, Samar. Profile on an east and west line.

platform to the 25-fathom line, where there is an upbuilding, then the depths become greater, with fluctuations, out to the Pacific Deep. Fig. 2 [fig. 6 of this paper] is a similar profile from Dolores to Hilaban Island and likewise may indicate subsidence.

[2] Schenck, H. G., Physiography and geology of Samar, P. I., Philip. Journ. Sci. 20 (1922) 248–252.

The evidence seems to favor the theory expressed by Davis [3] that the existence of earlier formed reefs at lower levels, now drowned, is highly probable in many of the Philippine islands; for the absence of strong cliffs on headlands or back shores indicates the presence of protecting reefs while the coasts were suffering erosion before their recent subsidence.

Elsewhere Davis states: [4]

On the other hand, the northeastern coast of Samar, on the opposite side of the archipelago from Palawan, has a moderately sinuous shore line with delta flats that diminish the initial size of its bays, and fringing reefs that reach forward a mile or so from its points; here the latest submergence cannot be so recent as that of Palawan. But instead of being benched by a submerged platform, the sea bottom off shore from Samar sinks rapidly to a great depth.
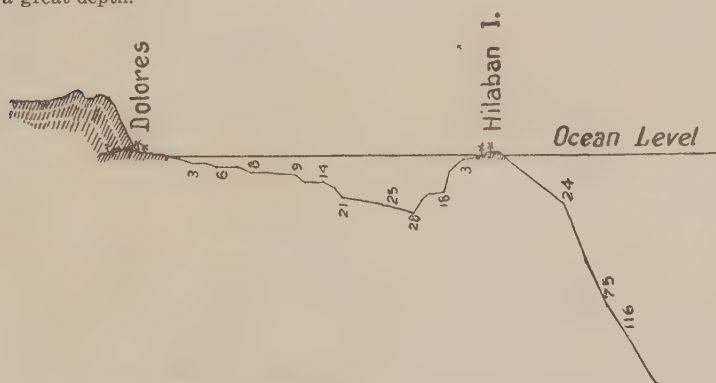
Fig. 6. Dolores to Hilaban, Samar. Profile on an east and west line.

Schenck's observations and Davis's interesting deductive studies which were based upon Coast and Geodetic Survey maps apparently indicate that the last movement on the eastern shore of Samar was one of depression (or rise of the sea according to Daly's Glacial Hypothesis). However, previous to this time evidences of the high terraces which are found to cross the middle portion of Samar are indicated by Schenck, as follows: [5]

At this point particular attention should be called to the long regular stretch of Dolores River from Hinolaso to Sumakay, to its long south-flowing

[3] Davis, W. M., Subsidence of reef-encircled islands, Bull. Geol. Soc. America **29** (1918) 517.

[4] Davis, W. M., Fringing reefs of the Philippine Islands, Proc. Nat. Acad. Sci. **4** (1918) 199.
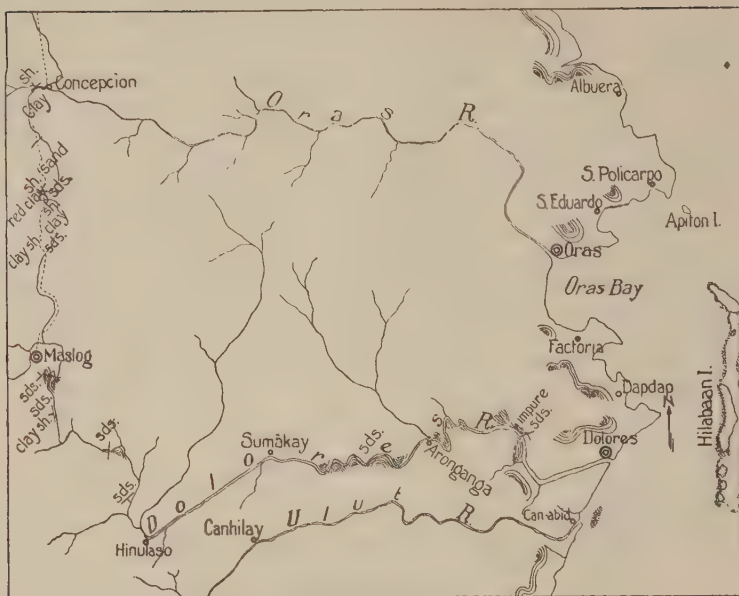
[5] Op. cit. 251.

Fig. 7. The drainage on the east coast of Samar. These rivers are probably intrenched in an old marine Pleistocene plain.

tributary, and to a straight stretch of Ulot River corresponding to that of Dolores River. Farther east both rivers meander to a great extent. [See fig. 7.] Assuming the presence of an elevated marine terrace and further assuming that these rivers are antecedent streams, this phenomenon is readily explained, though a low anticlinal structure might be the controlling factor. It has been pointed out that evidences of uplift have been noted at several localities—and the island shown in Plate 1, fig. 1, furnishes marked indication of a terrace—on the west coast of the island, while definite evidence is not so marked on the Pacific side, although a recurring element in profile of certain portions of the east coast, for example at Palapag Mesa, may point to uplift. Terracing may have been general in extent. I am convinced that the section of Samar just described represents an old Pleistocene marine terrace; should this prove to be the case, Dickerson's idea of extensive terracing would certainly carry considerable weight.

Seemingly, the terracing on Samar, Leyte, and Bohol and the local depression described indicate that the combined mass was controlled by about the same set of forces during the Pleistocene. Leyte was during this time, in all probability, a series of small islands; most of Bohol was covered during early Pleistocene by the shallow water of a coralline sea (see Plate 1, fig. 2); and large portions of Samar were in all probability likewise covered.

FIG. 8.   The Philippine Islands, showing marine Pleistocene areas.

Since the succession of uplifts in middle or late Pleistocene time
these three islands began to assume their present form and
the Pleistocene Leyte archipelago supplied the late Pleistocene
land masses with their present floras and faunas.   (See fig. 8.)

In Cebu, 64 to 80 kilometers west of Leyte, there is a vastly
different condition.   The Pleistocene history of Cebu is highly
complicated in detail and on this account only the broad out-
lines can be sketched.   The city of Cebu is built upon two
marine terraces, one about 3 meters above the present sea level
and the other rising from about 9 to 18 meters.   These two
terraces stretch to the south and north of Cebu city on the
east coast, giving a narrow but good means of travel along this
coastal stretch.   According to Smith, higher terraces, the upper-
most of which is 300 meters high, are well developed in the
hills near Cebu city.   Similar terraces, resting unconformably
on Malumbang limestone, were noticed on the west coast south
of Barili at approximately the same elevations.   A climb of 5
kilometers up the steep slopes from the village of Alegria on
the west coast ends upon a plateau whose elevation is approx-
imately 600 meters.   My Filipino assistant, Mark Fuken, upon
his own initiative, called attention to the remarkable evenness
of this surface.   This surface is cut across the truncate edges
of the Malumbang sandstone, whose prevailing dip is 30°.
Cebu is an upthrust block, Tañon Straits being the corresponding
depression block, in a well-marked northeast-southwest fault
system.   Cebu in early Pleistocene time was a string of coral-
line-topped islets, which in later Pleistocene were united to
form the Cebu of the present.

Recent explorations in Negros by Dr. W. D. Smith and Mr.
Palmer Beckwith indicate an extensive terracing.   A wide
marine terrace occurs on the west side and narrowly skirts the
east coast to the vicinity of San Carlos and beyond.   Accord-
ing to Smith, this uplift is further indicated by incised mean-
ders in the lower part of the volcanic plain which borders the
marine plain.

Negros was intimately connected with Guimaras, Panay,
Masbate, and Ticao during the Pleistocene.   This fact is nicely
brought out by tracing the 30-fathom line and the 100-fathom
line on the Coast and Geodetic Survey chart No. 4718, of Panay,
Negros, Cebu, and Masbate.   Negros and Panay are closely
connected to the northwest with Masbate by a sea which is
everywhere less than 30 fathoms (180 feet) in depth.   An

extensive series of marine terraces is reported by Abella, and later by Beckwith, in the vicinity immediately west of the town of Lucena, in central Panay. Five kilometers south of Ulian River, near Curoton, just north of Abangay River, marine gravel terraces of Pleistocene age rest unconformably upon a loose, fossiliferous sandstone of Malumbang age, about 40 kilometers north of the city of Iloilo in the central portion of Panay. Terraces are also reported farther to the north on the divide between Jalur and Panay Rivers. These marine terraces indicate that during one stage of the Pleistocene Panay was divided into at least two large islands. Some of these terraces reach an elevation of about 30 meters.

Guimaras is likewise terraced. Following the formation of terraces in Negros, Panay, Guimaras, and Masbate apparently the general region was uplifted without any marked faulting during the Pleistocene and a land mass of considerable extent in middle Pleistocene connected these large islands with Masbate to the northeast. Between the present sites of Panay and Negros to the south and Masbate to the northeast a broad low plain was developed. Ferguson first announced this interesting relationship in his paper upon the physiography of Masbate.[6] Further notes are given in a later paper upon the mineral resources of Aroroy district.[7] In the latter paper he states:

Submergence again continued, giving the series of limestone terraces that form such a prominent feature of the topography between Point Colorada and Point Bugui. It is to be inferred from the courses of the present streams that the Aroroy district itself was at one time, at least in great part, covered by sediments. None of the principal streams shows adjustment to the present topography, and all may properly be classed as superimposed. After the period of sedimentation, the land surface was elevated to a point probably some sixty meters above its present level, and remained at this elevation long enough for a deep valley to be eroded out of the soft shales. Recent depression has converted this valley into the present Port Barrera. [See Plate 2, fig. 2.] Still more recent elevation, but only to the extent of some five or six meters, is shown in the raised coral reefs found on the northern shore of Point Colorada and on the coast east of Buyuan Bay. [See Plate 2.]

These higher terraces are beautifully shown in Plate 2, fig. 1, and are apparently at least 200 meters in elevation. These

[6] Ferguson, H. G., Physiography of the P. I., western Masbate, Philip. Journ. Sci. § A **4** (1909) 1–17.

[7] Ferguson, H. G., The geology and mineral resources of the Aroroy district, Masbate, Philip. Journ. Sci. § A **6** (1911) 413.

upper terraces are in all likelihood to be correlated with the same stages of terracing in Panay and Negros. Concerning the later stage Ferguson says in his paper upon the physiography of Masbate, page 12:

The submarine contours of Nin Bay suggest depression rather than elevation and this would be in accord with the topography of the coastal plain. An elevation of 35 meters would connect Masbate with Panay by a narrow ridge containing Jinototo and the two Zapatos Islands, which would stand out as peaks above the rest of the ridge. Mr. Worcester, reasoning from zoölogical evidence, suggested that Masbate, Panay, Guimaras, and Negros were formerly connected, and at least as far as concerns Masbate and Panay, the physiographic evidence confirms this. Dr. Becker, following this and from a study of the charts of these waters, suggests the separation of these islands by the submergence of a coastal peneplain.

On page 11, Ferguson offers interesting data substantiating the ideas of recent submergence in late Pleistocene time by giving details on the region around Nin Bay on the west side of Masbate. He gives further support to Becker's idea of peneplanation in his discussion of Malbug River.[8]

A peculiar feature of the topography of this part of the island [vicinity of Milagros southwest coast of larger arm of Masbate] is the course of the Malbug River, which rises near the northeastern coast and flows southeast parallel to the coast, until near Uson it makes a sharp turn at right angles to its former direction and flows southwest into the Gulf of Asid. The largest rivers of the island, the Asid and Malbug, drain into the shallow Gulf of Asid. The crests of the mountain ranges lie near the northern shore, there being a considerable stretch of plain and piedmont country on the southwestern side of the main prong of the island. Similarly, the greatest depths near the shore are to be found along the northern and northeastern coast, especially between Naro Bay and Point Bugui, where there is a depth of 911 meters at a point less than 3 kilometers north of Bagubau Point, while off the southern coast shoal water extends for a great distance.   *   *   *   The excellent harbors of Port Barrera (Aroroy), Port Palanog (Masbate), Naro Bay (Dimas-Alang), and Port Kataingan are situated on the northern and eastern coasts. On the west coast the only harbor is Port Mandaon. The Gulf of Asid, on the south coast, is so shallow that only small boats can call at Milagros.

Concerning the same matter, Becker[9] summarizes the conditions as follows:

If, for example, Negros, Guimaras, Panay, and Masbate were now to be depressed, even 100 feet or so, a very wide interval, 30 miles or more, would exist between Negros and Panay, while nearly as great a distance would

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[8] Op. cit. 400.

[9] Becker, G. F., Report on the Geology of the P. I., U. S. Geological Survey, 21st Ann. Report Pt. III (1899–1900) 567.

intervene between Panay and Masbate. It is almost incredible that, in these quiet landlocked waters, connecting isthmian areas of such extent have been cut away by wave action and left no monadnocks to tell the tale. Inspection of the charts seems rather to indicate, in the shoal waters which separate this group of islands, a submerged coastal peneplain.

If a fluctuation such as is here suggested has occurred, it would have produced a nonconformity of erosion which would probably be traceable on minute study. It should certainly be sought when opportunity offers.

As Worcester and Bourns [10] point out, Negros, Panay, Guimaras, and Masbate are all of a zoölogical unit. McGregor (in litt.) notes that "the birds of Ticao show that this island belongs to the Masbate-Panay complex." A hydrographic map of this region has been drawn following the 30-fathom contour, 100-fathom contour, and the 200-fathom contour, to bring out the striking relationships described above (see fig. 9 and Plate 4). The cleverness of Becker's interpretation and the excellent support given to, and the strengthening of, his peneplain hypothesis by Ferguson, are excellent pieces of geological reasoning. However, there is no necessity in this case to postulate a broad, nearly uniform depression as the last event. A recent theory, which is particularly applicable to conditions such as are described above, in tropical regions, advances the explanation that the sea level rose at the close of the Pleistocene upon the restoration of waters previously withdrawn from circulation and tied up in glacial ice.

The first scientist to suggest a definite connection between the height of the sea level in the Tropics and the glaciation of the Pleistocene was A. Penck.[11] His statement is briefly set forth as follows:

The causes of the general rise of sea-level in the latest geological time might perhaps be connected with those climatic changes which the earth underwent in the Glacial period. If during that time, northern Europe, northern North America and the Antarctic regions were simultaneously glaciated, a considerable mass of water must have been removed from the ocean, and, if the thickness of the ice be assumed as 1,000 meters, the sea-level must have been 150 meters below its present position.

According to Daly,[12] the ice sheet at the 49th parallel of latitude, near the southern limit of the cap, was 6,000 feet

[10] Proc. U. S. Nat. Mus. **20** (1898) 549–625.

[11] Penck, A., Morphologie der Erdoberfläche **2** (1894) 660.

[12] Daly, R. A., Pleistocene glaciation and the coral reef problem, Am. Journ. Sci. IV **30** (1910) 299.

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maximum, with an average thickness of 2,000 feet. Daly regards Penck's estimate as somewhat too high. He says:

The removal of enough water to form these great sheets of ice would tend to lower sea-level all around the globe by the amounts here approximately stated.

Estimated average thickness of ice in feet.......... 3,000 3,600 4,000 5,000
Corresponding decrease of ocean's depth in feet..   125   150   167   208

Woodward, Hergesell, and others have shown that a second cause for a negative movement of sea-level in the equatorial zone is to be found in the

FIG. 9. Panay, Negros, and Cebu, and adjacent waters, showing isobaths.

gravitative power of ice. Using Woodward's formulas, it may be calculated that if the ice had an area of 6,000,000 square miles and an average thickness varying from 3,000 to 5,000 feet, the attraction of the ice would lower the level of the equatorial sea by amounts ranging from five to eight fathoms.

Taking the two effects together, the formation of the ice-sheets (which have since disappeared) would produce a negative movement of sea-level in low latitudes to an amount ranging between twenty to [and] forty-five fathoms. Assuming 3,000 feet as the average thickness of the ice, the shift of level in the equatorial sea would be about 30 fathoms.

As was indicated in previous discussion, without uplift this once broad, low-lying plain between Panay and Masbate has been partially covered by the waters restored from glacial ice at the close of the last phase of the Pleistocene, and the resultant drowned topography so beautifully exhibited in Masbate is now easily comprehensible. Upon the crest of the small elevations of late Pleistocene time coral polyps are now erecting their limestone platforms in the shallow area between Masbate and Negros (see Plate 4).

The startling conception of the Penck-Daly hypothesis surely aids greatly in interpreting this particular area. Apparently, this interpretation is further substantiated when the seaward extension of Cebu Island is studied.

Another interesting relationship exists between Ticao and Masbate. Ferguson calls attention to this in his papers referred to above. In his discussion of earthquakes [13] he states:

The Atlas de Filipinas divides the island between "rather frequent" and "rare" earthquake areas, the "rather frequent" zone lying, as would be expected, along the very deep Ticao strait between Masbate and Point Bugui. In a recent catalogue of destructive earthquakes, six earthquakes above VI of the Rossi-Forel scale are stated to have been felt in the years 1869, 1874, 1893, (two) 1897, 1900.

Recent work by Dr. A. N. Kryshtafovich upon Ticao indicates that Ferguson's ideas of faulting are quite correct. In addition, Kryshtafovich recognizes Ticao as a fault-block island with marked escarpment on the west and with gentle slopes toward the east. The mountain system of Ticao is apparently a very simple one, as a moderately elevated region with extreme altitudes of 322.5 to 348 meters with northwest-southeast trend, parallel to the southern branch of Masbate, runs close to its western shore in marked contrast to that of Masbate where the principal mountain range is situated closer to the eastern coast. The eastern shore of the island is low, abounding in deep bays

[13] Ferguson, H. J., Philip. Journ. Sci. § A **6** (1911) 401.

fringed with mangrove swamps in marked contrast with the steep and, in some places, even abrupt slopes on the west. This orographic condition is also reflected by the stream drainage, since all the important streams flow from the west to the eastern coast. Ticao is still connected at its southern extremity beneath the shallow waters of the sea with Masbate. Evidently the faulting which proved the separation of Ticao from Masbate is a comparatively late Pleistocene event, as coralline limestone of probable Pleistocene age has been given easterly inclination by the tipping of the block, since Ticao Strait is even now a decidedly seismic area. Movements along this fault line are probably continuing to-day, and the last movement recognized by Ferguson between low terraces in the vicinity of Point Colo-rada probably represents an exceedingly late Pleistocene or Recent uplift of the Masbate block.

But little is known concerning the Pleistocene of Palawan. A low, well-marked marine terrace occurs at Puerto Princesa according to photographs taken by Dr. Paul C. Freer, late di-rector of the Bureau of Science (see Plate 1, fig. 3). The embayments, such as Malampaya Sound, indicate the drowned river valleys of a former cycle during which the island was at a much greater elevation than it is at present (see Plate 3, fig. 1). The marine terrace of Puerto Princesa on the east coast and Table Point terrace on the west probably indicate a still earlier cycle during which submergence was greater than that of the Recent. At present, the shore line indicates drown-ing of such an order that the rise of the sea in these tropical regions of 30 fathoms—the estimate of Daly—would be more than sufficient to flood the stream valleys of the second cycle. The 30-fathom curve of the Coast and Geodetic Survey illus-trates this condition beautifully. The great limestone cliffs, 60 meters or more in height, which guard the entrance of Malam-paya Sound and encircle several of the Calamianes, are notable features of western Palawan and the neighboring islands. The cliffs of St. Paul's Bay and the drowned mouth of its underground river, which launches can enter from the sea and navigate for about 6 kilometers, all testify to a great period of wave and stream erosion during which the great, wide, now submerged coastal plain was cut from the land in a period of higher-standing land than the present (see Plate 3, figs. 1, 2, and 3). Undoubtedly, more physiographic evidence will be found when this island shall have been studied in detail. During this high-

standing period Palawan was probably definitely and broadly connected to the south with Borneo and to the north less strongly with Mindoro by a chain through the Calamianes as shown by the distribution of fresh-water fishes (see fig. 10). There are several suggestive coastal characters, such as the probable north-south Princesa fault which probably indicates a definite movement of the south half of Palawan upward with the north half correspondingly depressed, which complicate the picture and prevent us from drawing any but broad sketch lines of the history of this interesting elongate island (see fig. 11). The last event; at any rate in the northern half of the island, has been drowning, which as far as we can see may be explained by a down-movement along the Princesa fault or by the flooding of the restored glacial waters, or both, at the close of the Pleistocene.

Zoölogically and botanically the Calamianes and Palawan are in broad terms a unit with a dominantly Bornean flora and fauna. Mindoro is less strictly Bornean with more endemic species, both plant and animal, than Palawan. Such forms as the unique timarau (*Bubalus mindorensis*), a dwarf water buffalo, a distinct Asian form, is, judging by its resemblance to the common water buffalo, a species which developed in the late Pleistocene from an ancestral early Pleistocene or Pliocene type. Such endemism, which is probably the result of isolation, indicates that Mindoro was separated from Palawan previous to Palawan's separation from Borneo. The present known fragmentary story of Pleistocene geology of Mindoro leads to the same conclusion.

Mr. Graham B. Moody reports coralline limestone from Mindoro from Hospital Hill, which is about 300 meters in elevation, on the side of Lumintao River about 2.5 kilometers from this stream (121° 6′ east longitude, 12° 35′ north latitude). He says:

Coralline limestone containing large coral heads is found in a low hill on Amauking River about 1.5 kilometers northeast of the barrio of Calintaan (120° 56′ east longitude, 12° 35′ north latitude); in a low hill on the trail between Calintaan and Lumintao River in Caguray River about 0.5 kilometer due south of Doctor Daywalt's house and the terraced 117.5-meter Santa Teresa Hill (12° 16′ north latitude, 121° 8′ east longitude). The distribution of this coralline limestone indicates an emergence of at least 300 meters since Pleistocene time. Practically all of this limestone has been eroded away
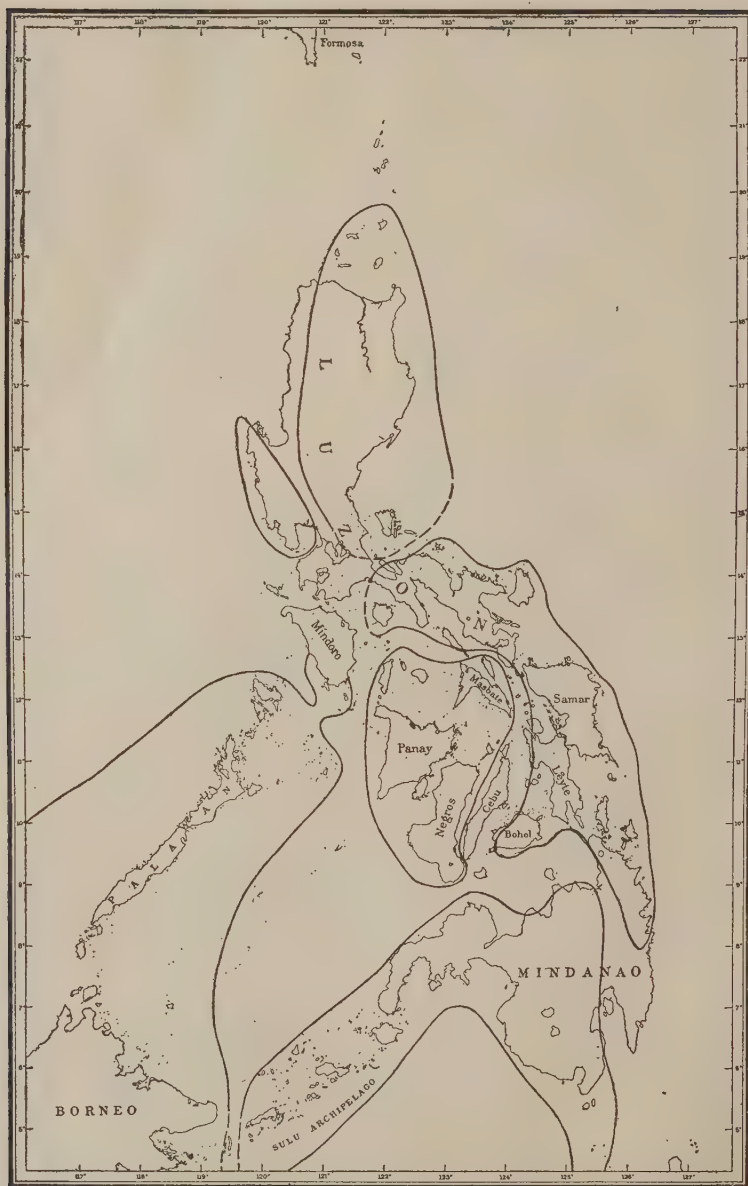
FIG. 10.   The Philippine Islands, showing some possible islands during early Pleistocene time.

Fig. 11. Central Palawan and adjacent waters, showing isobaths.

and but small residuals remain to evidence the presence of a Pleistocene sea. Bugsanga and Lumintao Rivers, which are large streams on the southwest coast of Mindoro, have nearly a parallel course for 32 kilometers upstream from their mouths. Now these streams in a place 24 kilometers upstream are separated by but 5 kilometers, a very remarkable fact when one remembers that they are master streams. The probable interpretation of this drainage is that these rivers started as streams on a low coastal plain which was so slowly uplifted that both streams maintained their courses by downward erosion against uplift. This once low coastal plain may correspond to the 300-meter terrace of Hospital Hill, and the later slow uplift stages may be recorded by the terraces of Santa Teresa Hill. Previous to the cutting of the 300-meter terrace Mindoro was, in all probability, more emergent than at present and was at that time connected to the south with Palawan.

Tablas Island probably emerged during late Pleistocene as an upthrust block between two well-marked faults. It is so recent geologically that its biological story is in all probability a short one. However, a biological study of such an island would give much interesting information which would contrast strongly with that of its richer neighbors.

The large island Luzon has had an exceedingly complicated Pleistocene history and, since but little attention has been paid to the study of marine terraces, there are great gaps in our knowledge of this interesting, irregularly formed island. In its western portion considerable study has been made of Bondoc Peninsula which lies within the longer and more irregular Camarines Peninsula. On the west side of Bondoc Peninsula, about 1.5 kilometers east of Pinamuntangan Point, at an elevation of 82.5 to 90 meters, a very excellently preserved Pleistocene fauna, containing gastropods and pelecypods in addition to the reef corals, establishes a definite Pleistocene horizon at this place. As Mr. Moody found in Mindoro, this occurrence is a mere residual, as the soft underlying shales and sandstone of the Vigo group have been easily eroded by the torrential rains of this region. A still higher terrace, about 150 meters in elevation, occurs in the region east of Mulanay poblacion, the principal town in the southern part on the west coast of this peninsula. In this vicinity there are several excellent residuals which evidence this now much-eroded marine terrace.

On both the west and the east sides of this peninsula one
of the notable physiographic features is the peculiar habit of
several of the master streams of breaking through a solid wall of
compact coralline limestone of Malumbang age. The Cata-
nauan, the Ajus, the Mulanay, the Matataha, the Ayni, and pos-
sibly the Silongin (Canguinsa) exhibit this habit on the west
coast, while the Guinhalinan, the Vigo, and the Bahay on the
east exhibit the same phenomenon of breaking through a
limestone wall with a wide shallow valley above. The history
of this peninsula is similar to that of the streams in the north-
west part of Leyte as described above. In Bondoc Peninsula
the master streams were practically all initiated upon a low
coastal plain that spread entirely across this peninsula. This
low coastal plain was for the most part covered by the sedi-
ments and coralline limestones of the early or middle Pleis-
tocene age, and a few monadnocks of a former cycle rose above
this even surface. As progressive uplift occurred these streams
began to incise this plain and exhumed the Vigo and Ma-
lumbang strata. The Vigo, being on the whole largely
composed of shales in this peninsula, was far more easily
eroded than the compact limestone of the Malumbang and,
back of the westerly or easterly dipping Malumbang limestone,
according to their respective coasts upon which these streams
occurred, wide valleys developed in the soft Vigo shales and
sandstones. At a later stage some drowning of these streams
may have occurred; but in practically all cases the resulting
bays have been filled by alluvium from the surrounding hills.
Pagsangahan River in the south end of the peninsula passes
through a valley whose feature is difficult to explain upon any
other hypothesis. Most of the streams are tidal for the lower
2 or 3 kilometers of their courses. The same condition prob-
ably prevailed through the northern half of this peninsula as
well. In the low divide between Calauag Bay and Ragay Gulf,
an excellent 9-meter terrace marked by coralline limestone,
which is found resting unconformably upon the truncate edges
of Vigo shales, clearly evidences a stage during which a Pleis-
tocene Camarines island existed. Based upon the study of the
terrace on the south end of Bondoc Peninsula, it is probable
that a wide channel existed at a still earlier stage of the Pleis-
tocene connecting the greater Limon Bay with the southern
Sibuyan Sea to the south. W. D. Smith reports the Paracale

district, Camarines, as being drowned. The general broken character of this region is in accord with his specially studied case, and here again drowning is probably the episode which closed the Pleistocene.

One of the most striking bits of coastal scenery occurs on the south coast of Batangas at Malbrigo Point. Fairly broad-stepped terraces, in beautiful succession, rise gradually to an uppermost tread of 180 meters. Well-marked evidence of a marine Pleistocene terrace is reported by Smith from the vicinity of Bamban, Tarlac Province, in the great valley of Luzon. So recent is the conquest of this great valley by the land from the sea that, within historic times, canoes have been enabled to pass during flood seasons from Manila Bay to Lingayen Gulf, and only within recent or late Pleistocene times, through a double process of uplift and filling, has the Pleistocene Zambales island been stoutly tied to its master, Luzon. Further evidence for this is found in the peninsula which forms the western side of Lingayen Gulf. On the westward or seaward side there exists a well-developed system of marine terraces upon which Mr. P. R. Fanning reports numerous residuals of coralline limestone. The low Cabarruyan Island in Lingayen Gulf also evidences uplift. This island has been rather recently disconnected from the mainland. From this island, near the town of Anda, a small tooth of a young individual of *Elephas* species is reported to have been collected.

Along the western coast of Ilocos Sur, Ilocos Norte, the Mountain Province, and a portion of La Union Province, well-marked marine terraces of two or three different stages are clearly seen. These terraces extend to an elevation of 75 to 90 meters in the coastal region south of Vigan. In the vicinity of the last-mentioned town, Abra River breaks through a 600-meter range of diorite but 3.2 kilometers from its mouth in the China Sea. The abrupt western face of this diorite range extends northeastward for many kilometers, and it is sharply set off from the marine terraces whose elevation approximates 30 to 45 meters. Evidently, this range has been rather recently thrust up along a well-marked rift whose general trend is north 15° east. This region of faulting is in all probability not wholly simple but consists of several parallel, or approximately parallel, faults, as that marked feature of recent rifting known as kernbuts occurs between these parallel faults. These kernbuts in the valley of Kern River, California, which are typically de-

scribed by Lawson,[14] are due to differential displacements between parallel faults. In addition to this well-marked feature, the water gap of the Abra near Vigan is inexplicable on any other basis than that of antecedency, as there is a far easier course across the softer Tertiary rocks a short distance south of Sulvec Point. By movement along the Abra Fault in late Pleistocene time this range of diorite was upthrust against the down-cutting Abra (see fig. 12). In this particular region faulting undoubtedly has complicated the Pleistocene problem greatly and in even late Pleistocene time great movements have occurred along many of these fault lines. This is quite evident when the region around Baguio and Trinidad in Benguet Subprovince, Mountain Province, is studied. Baguio City and Trinidad Valley are located on a high upland plateau, whose elevation is from 1,200 to 1,500 meters. The Tertiary history of this plateau has been worked out in some detail by Dickerson,[15] whose conclusions are that this plateau is a peneplain developed near sea level during early or middle Pleistocene time, hoisted by faulting on a great scale during the late Pleistocene and that, owing to the torrential tropical rains, much of its area has, even during late geologic and Recent times, been removed entirely from large areas. Only such residuals as the Baguio Plateau, Haight's Plateau, and Mount Data Plateau remain to evidence this once extensive upland. Farther to the east and north of this plateau higher mountains, attaining elevations of 1,200 to 1,500 meters, probably existed during the Pleistocene, and upon these higher and colder peaks the representatives of the early Formosan-Himalayan flora were preserved.

Cagayan River, in Cagayan Valley, northern Luzon, passes through low hills even a few kilometers south from Aparri, the port at its mouth; and, according to certain contour maps, this stream is intrenched in a series of low hills from which it has cut narrow shallow valleys. No definite information is available, but it seems entirely probable that Cagayan Valley was occupied by the sea during late Pleistocene time.

The Babuyan Islands, immediately to the north of Luzon, are in part limestone, in part volcanics. Fuga and Calayan Islands are, according to Mr. McGregor, ornithologist of the

[14] Lawson, A. C., The geomorphogeny of the Upper Kern Basin, Univ. Calif. Publ. Dept. Geol. No. 15 **3** (1902–1904) 291–376.

[15] Dickerson, R. E., The development of Baguio Plateau, Philip. Journ. Sci. **23** (1923) 413–453.
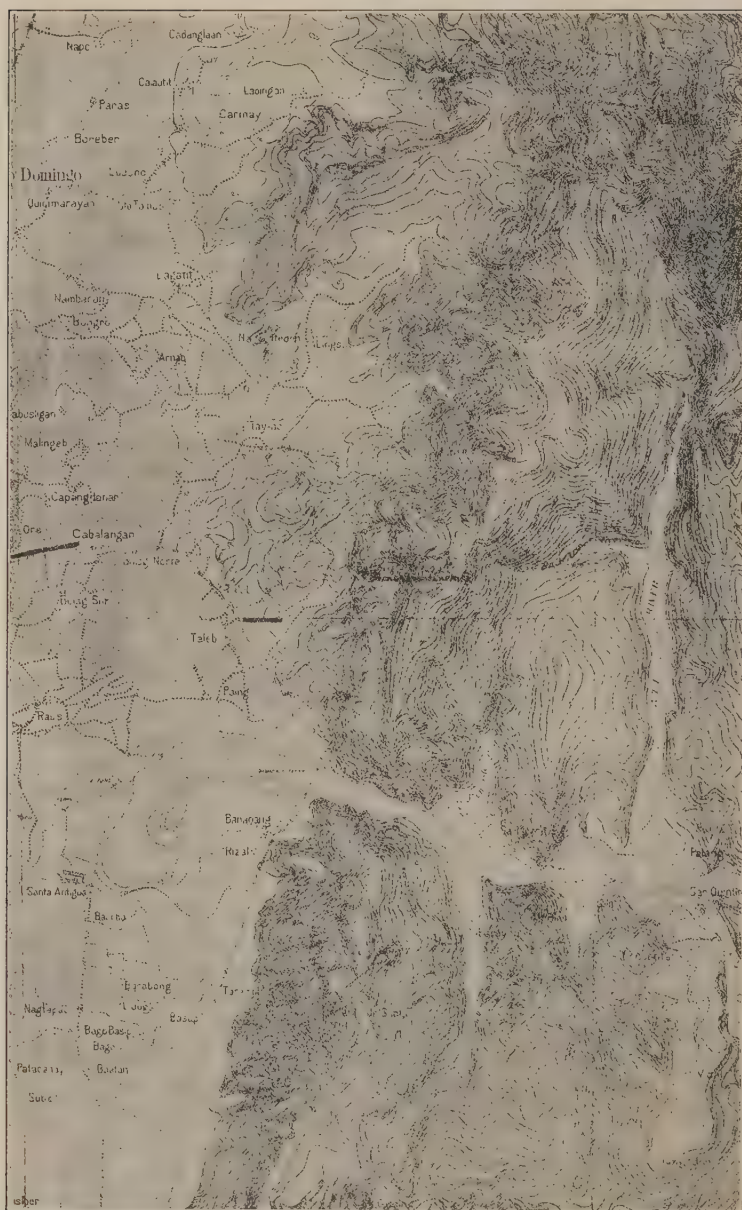
Fig. 12. Part of northern Luzon, showing Abra Water Gap.

Bureau of Science, composed of limestones; and these limestones, in turn, are cut by a series of terraces. Fuga is entirely composed of limestone, whereas Calayan exposes columnar lava also. The channel separating Fuga from the mainland is shallow. According to Ferguson, who visited Camiguin, this island is built up of various lava flows interbedded with volcanic agglomerate and is apparently a quite recent product of volcanism. Babuyan Claro, the island north of Camiguin, is volcanic, according to Ferguson. The Babuyan Islands are separated from the Batanes by Balintang Channel which has considerable depth. Of these islands, Ferguson reports a marine terrace at 270 meters on Batan Island and one at 210 meters on Sabtan Island. According to him: [16]

> The island of Ibujos consists entirely of coral limestone rising in steep cliffs to a height of over 60 meters. These surround the island, except on the eastern side where the land rises gently from the fringe of sand dunes and small ponds around the shore, in contrast to the 300-meter agglomerate cliffs of the island of Sabtan less than 2 kilometers distant. The surface of Ibujos is gently rolling, but without any streams or definite stream valleys. This condition is partly due to the solubility of the rock which allows water to run off in underground channels, but it is also in large part an effect of the recent date of the uplift, which has not allowed sufficient time for the streams to form valleys. * * *
>
> Isbayat, the largest island of the group is likewise entirely surrounded by cliffs, the only landings being steps cut in the rock in one place, and a series of ladders in the other. From the deck of the steamer the cliffs seemed to be similar to the limestone cliff of Diojo Point on the north of Batan Island, and I am told by people who have visited the island that the land slopes downward from the top of the cliffs toward the villages which are situated in small "sinks." This fact inclines me to believe that Isbayat is formed of limestone, rather than that it is of volcanic origin.

According to a letter written by an American school teacher, who for some time lived in Isbayat, the island contains notable caves in limestone. Y'Ami, the northernmost island of this group, is according to Ferguson volcanic except for a fringe of coral near the shore. The limestone reported upon these islands is probably of varying ages from Vigo-Miocene to Pleistocene, as one sample of *Lepidocyclina* limestone is in the collection of the Bureau of Science from Batan Island. The connection of the Batanes with the Babuyanes and, in turn, Luzon during the Pleistocene seems rather unlikely. The Babuyan Islands, on the other hand, may have been directly connected with Luzon during a high-standing period of this land mass during early Pleistocene.

[16] Ferguson, H. G., Philip. Journ. Sci. § A **3** (1908) 12.

SUMMARY

Such then are mere sketch lines of the intricate Pleistocene design but, although the gaps in the information are very great, certain of the larger features of the Pleistocene Philippine archipelago are clear in broad outline.

One of the most interesting results of this study of paleogeography of the Philippines is the conclusion that northern Luzon has during Vigo-Miocene, Malumbang-Pliocene, and Pleistocene times contained within its mass somewhere highstanding land with elevations of from 1,200 to 1,500 meters. The evidence for this conclusion is based upon the paleobotanical and botanical work of Elmer D. Merrill, former director of the Philippine Bureau of Science. On this continuously present Tertiary island of Luzon the remnants of a Himalayan-Formosan flora have been preserved. From the south during Vigo-Miocene time and, possibly, during the interval between the Vigo-Miocene and Malumbang-Pliocene times, the plants and animals of Malaysia spread northward upon the elongate Palawan-like island which probably existed on the eastern side of this archipelago. Not only did this land mass offer passage for the Celebesian forms of plant and animal life, but it seems highly probable that at this stage slight connections by way of a Talaur isthmus or island row were had with the Moluccas and, in turn, with New Guinea. The repeated appearance of this elongate island or row of islands during Malumbang time again offered a probable migration route for life forms. From this same Pliocene island or long island chain, Pliocene Leyte may have derived its fauna and flora and, in turn, a certain number of species may have spread to Negros and other island masses occupying, in part, the present sites of Negros and Panay.

The kaleidoscopic changes of the Pleistocene with its alternating cold and warm periods has left a peculiarly perplexing Philippine record, which can only be read by a study of the physiography of these islands. The great movements along dominant faults during the late Pleistocene and Recent times are absolutely astounding and the great acceleration of the processes of erosion due to the torrential character of the tropical rainfall startle the student of physiography whose training was obtained in more temperate climes.

The direct effects of glacial chill were, in all probability, damped in the Philippines, as the persistence of reef corals at

various Pleistocene horizons indicates warm marine waters throughout this period in this region. All the molluscan species thus far collected from Pleistocene beds are clearly referable to living forms. This indicates that no marked change in temperature of the Philippine sea water took place during the Pleistocene, since one of the most effective agents in producing specific change in marine littoral forms is temperature. However, the probable withdrawals of sea waters during the cold phases of the Pleistocene and their later restoration during the warm phases doubtless opened and shut many "portals" and these powerful indirect effects are reflected in the migrations of plants and animals and their very high specific endemism.

During the early Pleistocene a high-standing stage is recognized in northern Luzon during which a large portion of this region was reduced by subaërial erosion to a low-lying plain with mountains to the north and east of the present site of Baguio, Benguet, which attained a height of 1,200 to 1,500 meters. After this plain was developed the whole region was elevated in middle or late Pleistocene time, faulted, and during the late Pleistocene and Recent eroded so thoroughly that but relatively small remnants now record this Pleistocene history. The marine terraces along the western coast from Lingayen Gulf to Vigan and possibly farther north may represent the seaward edge of Baguio Plateau broken off by faulting from the rest of this notable feature.

The terraces of the Pleistocene Zambales island record a depression of at least 100 meters greater than the present during which this island was distinctly separated from the main mass of Luzon by a strait. Later through uplift and filling, this strait has been closed, thus tying this island to its present master, Luzon. During late Pleistocene time the waters of the Pacific Ocean had a free passage across the northern end of Bondoc Peninsula, and the Camarines island with its smoking sulphurous volcanoes of Mayon, Isarog, and Bulusan, dominated the central Philippine archipelago. Just what relation this Camarines island bore to the large land mass to the southwest is not clear. It is possible that a land connection existed in this direction. Panay, Masbate, Negros, and Ticao during early Pleistocene formed a compact mass upon which an extensive low-lying plain was developed during a high-standing stage of the land. During late Pleistocene, or even at the close of the

Pleistocene, this plain was covered by the waters restored by the melting of the glacial ice in high latitudes. Faulting was active along the northeastern portion of this land mass and Ticao was broken off and tilted and the intervening block sank beneath the sea.

During middle Pleistocene Samar, Leyte, and Bohol were largely submerged. Later they were uplifted and possibly for a short period united only to be separated again by the last flooding which merged into Recent time.

Mindanao had largely a separate history consisting of first, an elevated stage; second, erosion; third, a flooding with an archipelagic condition; fourth, union through uplift resulting in the second largest Philippine island of to-day.

Palawan was in early or middle Pleistocene broadly connected to the south with Borneo; then, possibly, great movements along the southern extension of Taal fault dropped in an extensive block on its western side, further elevating and outlining of Palawan took place, many rivers eroded such valleys as the one now occupied by Malampaya Sound and, finally, in latest Pleistocene time, this vassal of Borneo was freed from its dependent state and given an independent existence of its own.

ILLUSTRATIONS

PLATE 1

Fɪɢ. 1. Banisilan, Cotabato Province, Mindanao, looking west across the oldest river bench. Elevation about 375 meters above sea level.
2. Marine terrace in central Bohol. The rounded hills, which rise above the general level of this terrace, probably represent a series of stacks that have been rounded by erosion since the general region was uplifted. (Photograph by Bureau of Public Works.)
3. Puerto Princesa, Palawan.

PLATE 2

Fɪɢ. 1. The southern part of Aroroy district, looking south from Mount Bagadilla. (Photograph by Ferguson.)
2. Aroroy district, looking south and east from across Port Barrera. The two hills in the center are Mount Aroroy and Mount Bagadilla. (Photograph by Ferguson.)

PLATE 3

Fɪɢ. 1. Malampaya Sound, Palawan.
2. St. Paul's River, Palawan. Entrance to cave.
3. Headlands of St. Paul's Bay, Palawan.

PLATE 4

Topographic and hydrographic map of the Philippines.

TEXT FIGURES

Fɪɢ. 1. Sketch map of the Philippine Islands, showing hypothetic connections during pre-Vigo time.
2. Map showing probable islands in the Philippine area during Vigo-Miocene time.
3. Map showing some probable Pliocene islands of the Philippine area. Shading represents marine Pliocene rocks.
4. Map showing Mindanao islands during early or middle Pleistocene.
5. Taft to the Pacific Ocean, Samar. Profile on an east and west line; latitude, 11° 54' 48''; longitude, 125° 25' 30''. Scale: Horizontal, about 1:150,000; vertical, about × 6. Depths in fathoms, from Coast and Geodetic Survey sheet 1422. (After Schenck.)
6. Dolores to Hilaban Island, Samar. Profile on an east and west line; latitude, 12° 02' 20''; longitude, 125° 29'. Scale: Horizontal, 1:150,000; vertical, × 8. Depths in fathoms, from Coast and Geodetic Survey sheet 1422. (After Schenck.)

FIG. 7. Map showing the drainage on the east coast of Samar. These
          rivers are probably intrenched in an old marine Pleistocene
          plain.   (After Schenck.)
      8. Map showing marine Pleistocene areas in the Philippines.
      9. Isobathic map of Panay, Negros, and Cebu.   Prepared by Mr. John
          Bach, under the direction of Capt. E. H. Pagenhart, director,
          Bureau of Coast and Geodetic Survey.
      10. Map showing some possible Philippine islands during early Pleis-
          tocene time.
      11. Isobathic map of central Palawan.
      12. Contour map of a part of northern Luzon showing Abra Water
          Gap.
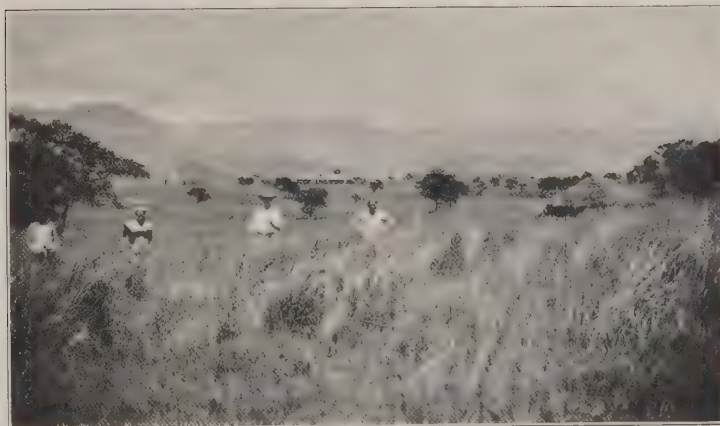
Fig. 1. Banisilan, Mindanao, looking west across the oldest river bench.
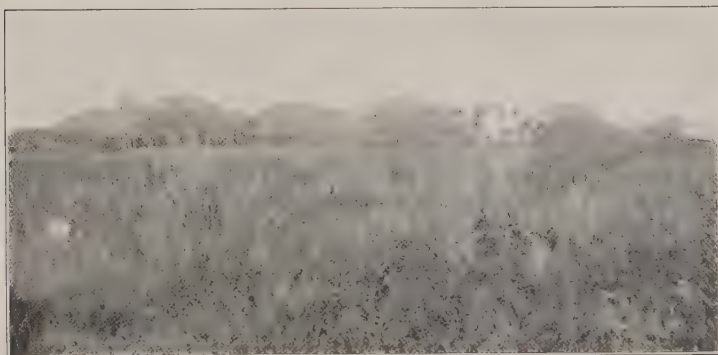
Fig. 2. Marine terrace in central Bohol.

Fig. 3. Puerto Princesa, Palawan.

PLATE 1.

Fig. 1. The southern part of Aroroy district, looking south from Mount Bagadilla.

Fig. 2. Aroroy district, looking south and east from across Port Barrera.

PLATE 2.

Fig. 1.   Malampaya Sound, Palawan.

Fig. 2.   St. Paul's River, Palawan.   Entrance to cave.
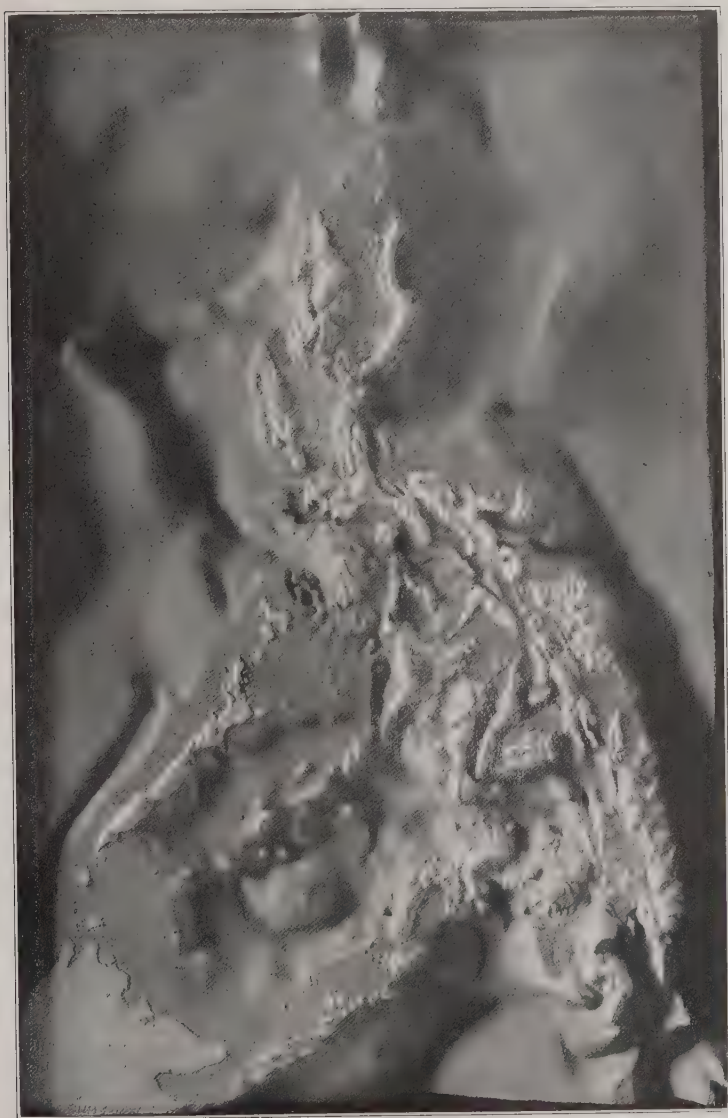

Fig. 3.   Headlands of St. Paul's Bay, Palawan.

PLATE 3.

PLATE 4. THE PHILIPPINE ISLANDS, SHOWING   THE TOPOGRAPHY AND THE
HYDROGRAPHY.

ABSORPTION OF CULTURE SOLUTIONS BY COCO-PALM ROOTS [1]

By R. B. Espino and Jose B. Juliano

Of the College of Agriculture, Los Baños

SIX TEXT FIGURES

INTRODUCTION

The present study deals with the rate of absorption of complete nutrient solutions by the roots of the coco palm (*Cocos nucifera* Linnæus). The results of this study may be of value to indicate the amount of water that the plant requires. It may also suggest something with regard to its fertilizer requirements.

Copeland,[2] working with the San Ramon type of coco palm, performed a similar study under the environmental conditions in San Ramon, Zamboanga, Mindanao. He found that the rate of absorption of solution of potassium nitrate varied with the different concentrations tested. Complete nutrient solutions have never been tried with the coco palm. Other plants, such as wheat,[9] buckwheat,[7, 8] and rice,[4] when grown in some complete and balanced culture solutions showed normal growth— much better than that obtained from similar plants when grown in single-salt solutions. Osterhout[6] found that single-salt solutions are far more toxic to plants than solutions containing two or more salts. For this reason it was deemed advisable to amplify the studies made by Copeland and to try complete nutrient solutions. The Laguna variety of coco palm, grown at the College of Agriculture, Los Baños, Luzon, was employed in the present study, which lasted from September, 1921, to December, 1922, inclusive.

EXPERIMENTS AND RESULTS

CULTURE SOLUTIONS EMPLOYED

Eight different sets of molecular salt proportions, as shown in Table 1, were used for this type. They all had the same

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[1] Thesis presented for graduation from the College of Agriculture; Experiment Station contribution, No. 233.

total concentration of 0.0245 gram-molecule of the salts per liter. These will be known as the 3-salt type.

Twelve culture solutions, as given in Table 2, were tested for this type, and each of them had a total concentration of 0.0384 gram-molecule of all salts per liter. These will be designated as the 4-salt type.

In the later part of this study only two culture solutions of the 3-salt type and three of the 4-salt type most readily absorbed were further tested. Four concentrations, 0.0192, 0.0384, 0.0768, and 0.1152 gram-molecule of all the salts per liter, were employed in the case of the 4-salt type except that culture solution B_4 had 0.0960 gram-molecule because precipitates were formed in concentrations higher than this one. The cultures of the 3-salt type were 0.01225, 0.0245, 0.0490, and 0.0980 gram-molecule (of all the salts employed) per liter.

PREPARATION OF THE SINGLE-SALT STOCK AND CULTURE SOLUTIONS

The single-salt stock solutions were prepared separately in half-molar concentration by using distilled water and "Baker's analyzed" monopotassium phosphate (KH_2PO_4), calcium nitrate [Ca $(NO_3)_2$], magnesium sulphate ($MgSO_4$), and ammonium sulphate [$(NH_4)_2SO_4$].

TABLE 1.—*Proportion of the single-salt solutions in each culture solution.* [a]

[Total concentration, 0.0245 gram-molecule of all salts taken together per liter.]

Culture solution.	Gram-molecule of each salt in culture solutions.		
	Monopotassium phosphate, KH_2PO_4.	Calcium nitrate, Ca $(NO_3)_2$.	Magnesium sulphate, $MgSO_4$.
A_3	0.0035	0.0035	0.0175
B_3	0.0035	0.0105	0.0105
C_3	0.0035	0.0175	0.0035
D_3	0.0070	0.0070	0.0105
E_3	0.0070	0.0105	0.0070
F_3	0.0105	0.0035	0.0105
G_3	0.0105	0.0105	0.0035
H_3	0.0175	0.0035	0.0035

[a] Some of the solutions employed by Espino.

TABLE 2.—*Proportion of the single-salt solutions in each culture solution.* [a]

[Total concentration, 0.0384 gram-molecule of all salts taken together per liter.]

Culture solution.	Gram-molecule of each salt in culture solutions.			
	Ammonium sulphate, $(NH_4)_2 SO_4$.	Monopotassium phosphate, KH_2PO_4.	Calcium nitrate, $Ca(NO_3)_2$.	Magnesium sulphate, $MgSO_4$.
A₄	0.0048	0.0048	0.0048	0.0240
B₄	0.0048	0.0048	0.0144	0.0144
C₄	0.0048	0.0048	0.0240	0.0048
D₄	0.0048	0.0096	0.0096	0.0144
E₄	0.0048	0.0096	0.0144	0.0096
F₄	0.0048	0.0144	0.0048	0.0144
G₄	0.0048	0.0144	0.0144	0.0048
H₄	0.0048	0.0240	0.0048	0.0048
I₄	0.0144	0.0048	0.0048	0.0144
J₄	0.0144	0.0048	0.0144	0.0048
K₄	0.0144	0.0144	0.0048	0.0048
L₄	0.0240	0.0048	0.0048	0.0048

[a] Some of the solutions employed by Espino.

In the proportions indicated in Tables 1 and 2 each solution was prepared by mixing the required amount of salts in a flask about two-thirds full of distilled water. One by one the salt solutions were poured into the flask. In order to avoid the formation of precipitates the contents of the flask were shaken while each salt solution was being added. A few drops of ferric chloride solution were added to each mixture, and water was further added up to the mark on the neck of the flask. The culture solution was then ready for use.

Sixty cubic centimeters of each culture solution were poured into a 100-cubic-centimeter bottle. Into this mixture a root of a coco palm was inserted to a length of about 5 centimeters. A paraffined cork stopper of suitable size and cotton fiber plugged the mouth of the bottle. This was done in order to avoid the loss of water from the mixture through evaporation. During the early part of the study each culture solution was renewed every three days; but later, when the study was mainly on the concentrations of the culture solutions, the interval was reduced to two days. Still later the renewal was made daily.

The roots were dug out of the ground. Care was taken not to bruise or injure them. Then they were washed with water and the portion of each root not needed in the experiment was again buried in the ground. These roots were placed separately in bottles of water for several hours. Thence, they were transferred into the culture solutions contained in bottles, each of which was laid in one-half of a split bamboo joint; the other half was then placed over it. This step was taken to insure cleanliness and darkness for the root. A shelter of suitable size was built around the stem of each tree about 1.5 meters from the ground. This shelter kept the rain and sun heat from interfering with the experiments.

At the time of changing the solution the bamboo joint was opened. The bottle was carefully removed and the amount of the solution absorbed was determined by weighing. Care was always exercised to effect the change of a culture solution within one minute.

FURTHER PLAN OF EXPERIMENTS AND RESULTS

Some roots from one coco palm about five years of age were employed as the living indicators of this study. Eight roots from the tree were supplied with the eight culture solutions of the 3-salt type. Each culture solution was tried on every root, but on different days, and had a concentration of 0.0245 gram-molecule of all salts taken together per liter. The results of the experiments are summarized in Tables 3 and 4.

Each of the twelve culture solutions of the 4-salt type was served to every one of the twelve roots of the same tree. Only one concentration (0.0384 gram-molecule per liter of all the salts together) of the culture solutions was here employed. The summary of the results obtained is given in Tables 5 and 6.

The two culture solutions E_3 and G_3 from the 3-salt type most readily absorbed were further tested in four different concentrations. These were 0.01125, 0.0245, 0.0490, and 0.0980 gram-molecule of all the salts together per liter. Culture E_3 in the four molecular concentrations was supplied alternately or in cycle to four roots from one tree. In a similar manner culture G_3 was supplied to another set of four roots, but from another tree.

TABLE 3.—*Average daily absorption records exceeding 1 gram; compiled from the data on hand.*

[All readings in grams.]

Culture solution.	Root 1.	Root 2.	Root 3.	Root 4.	Root 5.	Root 6.	Root 7.	Root 8.	Root 9.	Roots which absorbed the solution rapidly.
A_1						1.215				1
B_3			1.208							1
C_3										0
D_3										0
E_3							1.115	1.260		2
F_3				1.056	1.089					2
G_3	1.014	1.273	1.026				1.077			4
H_3		1.001	1.036							2

TABLE 4.—*Records of average daily absorption. Two culture solutions most readily absorbed by each root were selected from data on hand.*

[All readings in grams.]

Culture solution.	Root 1.	Root 2.	Root 3.	Root 4.	Root 5.	Root 6.	Root 7.	Root 8.	Average.	Roots with readings of each solution.
A_2					0.934		1.215		0.818	2
B_3				1.208		0.899			0.805	2
C_2			0.972						0.735	1
D_3									0.608	0
E_2	0.872	0.977					1.115	1.260	0.866	4
F_3					1.089				0.817	1
G_3	1.014	1.273		1.056				1.077	0.825	4
H_3			1.001	1.036					0.808	2

TABLE 5.—*Records of average daily absorption, exceeding 1 gram; compiled from data on hand.*

[All readings in grams.]

Culture solution.	Root 1.	Root 2.	Root 3.	Root 4.	Root 5.	Root 6.	Root 7.	Root 8.	Root 9.	Root 10.	Root 11.	Root 12.	Roots which absorbed the solution rapidly.
A_4		1.595	1.763		1.312						1.467	1.205	5
B_4		1.429	1.670									1.500	3
C_4													0
D_4													0
E_4		1.401	1.051	1.011		1.334	2.149						5
F_4			1.252				1.631						2
G_4							1.103		1.354	1.373			3
H_4									1.125				1
I_4							1.188			1.117	1.064		3
J_4							1.477						1
K_4												1.115	1
L_4	1.325			1.134									2

TABLE 6.—*Records of average daily absorption. Three culture solutions most readily absorbed by each root were selected from data on hand.*

[All readings in grams.]

Culture solution.	Root 1.	Root 2.	Root 3.	Root 4.	Root 5.	Root 6.	Root 7.	Root 8.	Root 9.	Root 10.	Root 11.	Root 12.	Average.	Roots with readings of each solution.
A₄	0.987	1.595	1.763	0.846	1.312			0.903			1.467	1.205	1.029	8
B₄		1.429	1.670	0.978	0.799	0.904		0.735	0.717			1.500	0.911	8
C₄									0.763			0.854	0.618	2
D₄						0.982							0.588	1
E₄	0.755	1.401	1.051	1.011		1.334	2.149	0.570					0.879	7
F₄	0.772		1.252	0.899			1.681						0.675	4
G₄						0.955			1.354	1.173			0.677	3
H₄									1.125	0.817			0.582	2
I₄	0.505				0.800		1.188			1.117	1.064		0.679	5
J₄							1.477			0.818	0.852		0.616	3
K₄											0.981	1.115	0.522	2
L₄		1.325			1.134			0.955					0.710	3

This procedure was also followed in connection with cultures A_4, B_4, and E_4, in four different concentrations supplied to a set of four roots from a tree. Four roots from each of five coco palms were here used as living indicators. With this arrangement the data in Table 7 are not always comparable with one another. Only the data in each column are comparable with one another, while the numerical data in the horizontal lines should not be compared with one another because they represent average daily absorption of roots of four different trees. The data for the 4-salt and those for the 3-salt culture solutions shown in Table 7 were compiled from the mass of data on hand.

TABLE 7.—*Average daily absorption* [a] *of each culture solution of different concentrations by the different roots.*

Concentration of culture solution. Gram-molecule of all salts per liter.	Culture solutions.				
	A_4	B_4[b]	E_4	E_3	G_3
	g.	*g.*	*g.*	*g.*	*g.*
0.0192	0.4288	0.2198	0.2471		
0.0384	0.4369	0.3045	0.3301		
0.0768	0.5167	0.3114	0.3904		
0.1152	0.5566	0.3566	0.4728		
0.01225				0.2871	0.3340
0.02450				0.2943	0.3374
0.04900				0.3101	0.3939
0.09800				0.2730	0.3196

[a] Numerical data in each column are comparable with one another; those in the horizontal lines, not.
[b] Concentration was 0.0960 gram-molecule of all the salts taken together per liter. Precipitates formed when concentrations were greater than this one.

As shown in preceding tables the culture solution most readily absorbed from the 3-salt type was E_3, and the one from the 4-salt type was A_4. These two cultures were compared under the same concentration, 0.098 gram-molecule (of all the salts taken together) per liter. Two roots from the same tree were here employed, and readings on absorption were taken once a day. The data are given in Table 8.

It was realized that a fair comparison of the two cultures (A_4 and E_3) was not possible, as they were both under the same concentration. The data in Table 7 show that, while concentration 0.098 gram-molecule was somewhat too strong for E_3, yet it was too weak for culture A_4. To make a logical comparison these two cultures were tried again. The E_3 had the concentration as shown best in Table 7, and A_4 had two concentrations; namely, the best and highest ever tried and another

TABLE 8.—*Comparative rate of daily absorption of a 3-salt culture solution and a 4-salt culture solution of equal molecular concentration.*

[0.098 gram-molecule (of all salts taken together) per liter.]

Date of observation.	Root 1.		Root 2.	
	Culture A 4.	Culture E 3.	Culture A 4.	Culture E 3.
	g.	*g.*	*g.*	*g.*
September 30		0.910	0.275	
October 1	0.980			0.250
October 2		0.575	0.445	
October 3	0.460			0.105
October 4		0.965	0.470	
October 5	1.565			0.290
October 6		0.405	0.420	
October 7	0.475			0.570
Average daily	0.870	0.713	0.352	0.303

a little stronger.   The results from these cultures together with their respective molecular concentrations are given in Table 9.

Culture solution A_4 of the 4-salt type was found to be more readily absorbed than was culture solution E_3 of the 3-salt type. The A_4 was then selected for hourly absorption tests.   As shown in Table 10 this set of tests was begun at 6.00 p. m. and ended at 6.00 p. m., twenty-four hours later.   The results of the experiments together with data on weather during the period of observation are indicated in Table 10.

—   DISCUSSION OF RESULTS

EXPERIMENTAL DIFFICULTIES AND HOW THEY WERE MET

Few cultures in a set; variation in roots.—The variation in the roots and the small number of cultures in a set would have presented real experimental difficulties and sources of error were it not for the fact that the culture tests were run in a system of cycles.   With this arrangement it was possible to test every root with every culture solution in a set.   The first set contained data from eight cycles, while twelve cycles were made for the second set.   In other words, sixty-four culture tests were made with the 3-salt type, and with the 4-salt type there were one hundred forty-four tests.   Hence, the results in terms of averages are valuable and conclusive.

Climatic fluctuations.—The fluctuations of certain climatic factors, such as rainfall, temperature, and others, might also interfere with the uniformity of results to be obtained from two or more similar culture tests in the different cycles; but

TABLE 9.—*Comparative rate of absorption of two best culture solutions with the most suitable concentration found.*

[Culture A₄ was tried in two concentrations.]

Date.	Solution tested.	Root 1.	Root 2.	Root 3.	Root 4.	Root 5.	Root 6.	Root 7.	Root 8.	Root 9.	Average daily absorption of each of the culture solutions.		
											A_4 (0.1536).	A_4 (0.1152).	E_3 (0.0490).
		g.	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*
February 23	A_4(0.1536)	1.025			0.495			0.055			0.525		
Do	A_4(0.1152)		0.855			0.425			0.115			0.465	
Do	E_3(0.0490)			0.155			0.285			0.350			0.263
February 24	A_4(0.1536)		0.435			0.475			0.700		0.534		
Do	A_4(0.1152)			0.205			0.290			0.420		0.305	
Do	E_3(0.0490)	0.610			0.160			0.120					0.296
February 25	A_4(0.1536)			0.260			0.420			0.490	0.390		
Do	A_4(0.1152)	0.590						0.165				0.377	
Do	E_3(0.0490)		0.490						0.170				0.220
February 26	A_4(0.1536)	3.080			0.465			0.280			1.275		
Do	A_4(0.1152)		0.925			0.780			0.540			0.748	
Do	E_3(0.0490)			0.255			0.705			0.260			0.406
Average per day											0.546	0.476	0.296

TABLE 10.—*Hourly absorption of a culture solution (A₄) of the 4-salt type in milligrams.*

[Total concentration of 0.1152 gram-molecule of all salts taken together.]

Time.	Absorption.				Average absorption.	Temperature.	Weather observation.
	Root 1.	Root 2.	Root 3.	Root 4.			
October 7.							
	mg.	*mg.*	*mg.*	*mg.*	*mg.*	*°C.*	
6 to 7 p. m _____	60	35	45	55	48.75	26	Calm, little shower.
7 to 8 p. m _____	30	20	35	45	32.50	25	Calm.
8 to 9 p. m _____	40	20	35	30	31.25	24	Slight breeze.
9 to 10 p. m _____	50	15	25	25	28.75	24	Calm.
10 to 11 p. m _____	60	20	45	10	33.75	24	Slight breeze (10.45).
11 p. m. to 12 midnight_____	15	15	35	20	21.25	24	Slight breeze (11.45).
October 8.							
12 midnight to 1 a. m _____	45	15	25	50	33.75	24	Slight breeze.
1 to 2 a. m _____	35	15	35	25	23.25	24	Slight breeze (1.45).
2 to 3 a. m _____	20	15	25	20	20.00	23.5	Calm.
3 to 4 a. m _____	10	10	10	20	12.50	24	Do.
4 to 5 a. m _____	20	10	20	10	15.00	24	Do.
5 to 6 a. m _____	15	5	35	35	22.50	23.5	Do.
6 to 7 a. m _____	20	10	30	50	29.50	27.5	Calm, diffused light.
7 to 8 a. m _____	35	20	30	75	40.00	29	Sunny.
8 to 9 a. m _____	60	25	45	80	52.50	29.5	Diffused light, light breeze.
9 to 10 a. m _____	70	35	65	80	62.50	31	Shiny, little diffused light.
10 to 11 a. m _____	70	55	70	90	71.25	28.5	Light breeze, shower, sunny.
11 a. m. to 12 noon__	55	55	75	70	63.75	31	Diffused light.
12 noon to 1 p. m ___	90	70	65	60	71.25	28.5	Shower, shiny, light breeze.
1 to 2 p. m _____	90	95	105	100	97.50	28.5	Sunny, light breeze.
2 to 3 p. m _____	75	80	95	90	85.00	28	Cloudy, windy.
3 to 4 p. m _____	20	20	60	50	37.50	27.5	Shower, cloudy.
4 to 5 p. m _____	70	45	55	60	57.50	27.5	Cloudy, calm.
5 to 6 p. m _____	65	40	45	50	50.00	27	Do.
Total_____	1,120	745	1,110	1,200	1,016.25		
Average absorption per hour _____	_____	_____	_____	_____	42.34		

care was taken to subject all the cultures in a cycle to the same set of climatic conditions. Hence, the results from the tests, especially when expressed in averages, are satisfactory and valuable.

Rapid absorption not always most beneficial to plants.—Investigators (5, 4) working on salt requirements of plants found that, in some cases but not always, the concentration is correlated with the rate of absorption. That is, the rate of absorption of a culture solution by the roots of higher plants decreases as the concentration is increased, or vice versa. The same investigators found that there is a concentration optimum for the plant and any alteration of this concentration was always followed by a corresponding decrease in growth or development of the plant. However, it was found that a concentration weaker than that of the optimum was always followed by increased absorption and transpiration, but somehow the plant remained undernourished. A question may therefore be raised as to whether or not the most rapid absorption observed in the present study can be expected to give a corresponding most beneficial effect to the coco palm.

The culture solutions indicated in Table 1 or those in Table 2 were different from one another only in the molecular proportions of the constituent salts, but the same in molecular concentration; therefore, the solution most readily absorbed supplied to the coconut tree the largest number of the molecules of the solutes. This is in accord with Avogadro's law. Hence, such a solution should be preferred. In this study this point of view is entertained.

COMPARATIVE MERITS OF 3-SALT AND 4-SALT CULTURE

Tests on salt molecular proportions.—The mass of data on hand, which are summarized in Tables 3 to 6, inclusive, plainly show that the rate of absorption of the culture solutions tested both in the 3-salt and in the 4-salt type varies according to the molecular proportion of the salts. These tables show that E_3 was almost always the best in the lot. However, the records on average daily absorption for the 3-salt type shown in Table 7 point to culture solution G_3 as being better than E_3. This is so because these two cultures were not tried on the same tree. The superiority of G_3 over E_3 might have been due to differences in vigor of the two trees. In Table 4, however, culture solution E_3 was almost as good as G_3, and the data on the relative rate of absorption of culture solutions (averaged from eight roots per day) as shown in fig. 1 give E_3 as more readily absorbed than G_3.

The data in Tables 5 and 6 obtained from the 4-salt set show that culture solutions A_4, B_4, and E_4 gave the best results of

Culture solution.

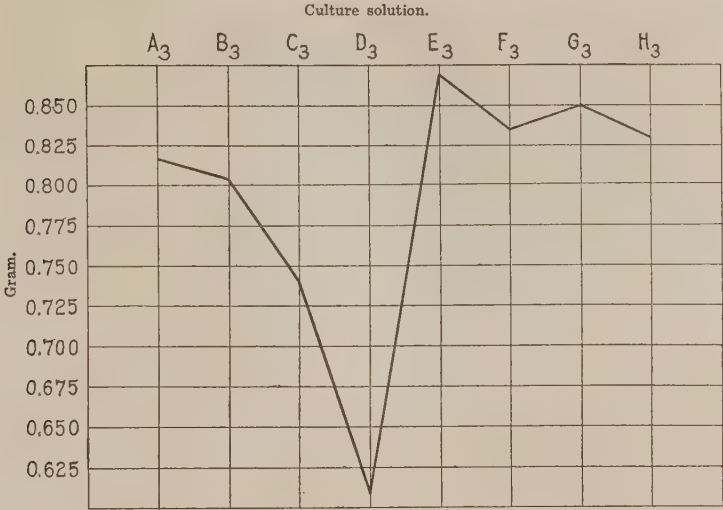| A₃ | B₃ | C₃ | D₃ | E₃ | F₃ | G₃ | H₃ |

Fig. 1. Showing relative rate of absorption of culture solutions, averaged from eight roots per day.

the lot.   In terms of relative rate of absorption (averaged from twelve roots per day) fig. 2 also indicates that these solutions are characterized by having low molecular proportions of mono-potassium phosphate and of ammonium sulphate, low to medium content of calcium nitrate, and high to medium content of
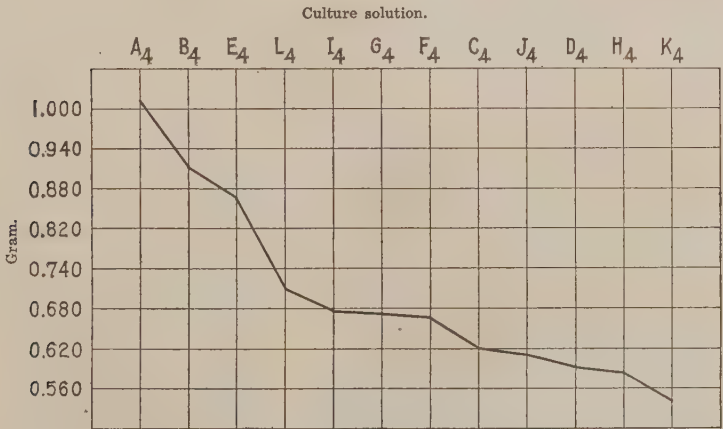
Culture solution.

| A₄ | B₄ | E₄ | L₄ | I₄ | G₄ | F₄ | C₄ | J₄ | D₄ | H₄ | K₄ |

Fig. 2. Showing relative average rate of absorption of culture solutions by twelve roots per day.

magnesium sulphate. Therefore, it appears that the molecular proportion of the salts in the solutions that gave good results on young lowland rice plant (variety Wateribune) (4) also gave a similar beneficial effect to the coco palm. However, the coconut tree seems to require a more concentrated solution than that which was best for the rice plant.

Further tests.—The data in Table 7, which were intended for tests on concentrations, also seem to show the superiority of the 4-salt culture solution A_4 over any other solution of that type. It was also better than any one of the 3-salt type tested.
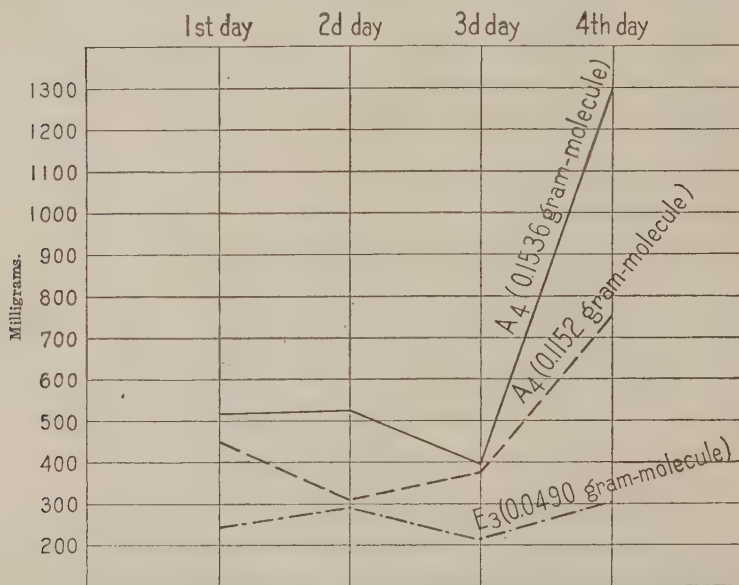
FIG. 3. Showing the superiority of A_4 over E_3. The graphs are built from the data in Table 8.

The data in Tables 8 and 9 plainly show also the superiority of A_4 over E_3; this superiority is graphically demonstrated in fig. 3 and fully confirms the results obtained by Bacomo, (1) in which he observed a rapid growth of coco seedlings following an application of sulphate of ammonia to the soil where the plants were growing.

Influence on rate of absorption by concentration.—The graphs in fig. 4 which are built out of the data in Table 7 conclusively demonstrate that the best concentration (0.049 gram-molecule) in the 3-salt type was much weaker than the best concentration

(0.1152 gram-molecule) in the 4-salt type.   That a decrease or
an increase in concentration of either of the two 3-salt cultures
tested was accompanied by a corresponding decrease in the rate
of absorption is also well shown in fig. 4.   With the 4-salt
culture solutions, however, the concentration that can very well
be called optimum for the coco palm has probably not been found;
for the strongest concentration of the best culture solution A_4
gave the highest records on absorption.   The data in Table 9
as well as the graphs in fig. 4 confirm this statement.   Further
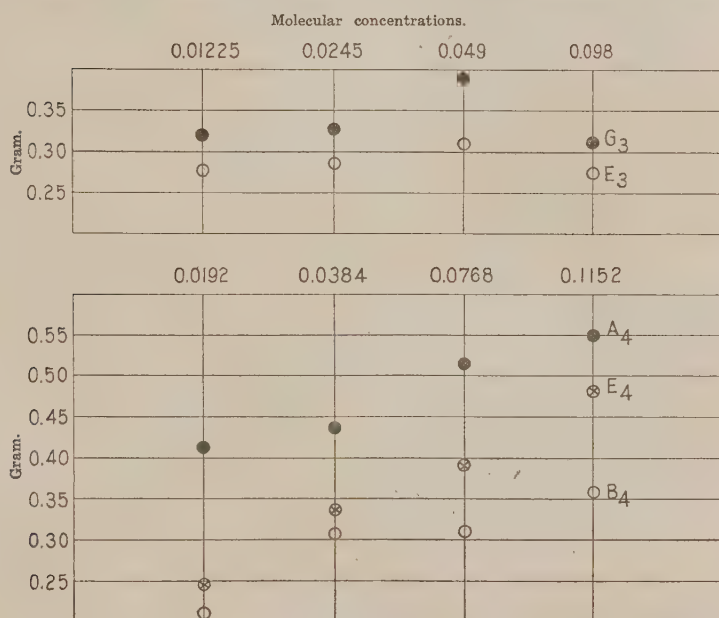
Fig. 4.   Showing rate (average) of absorption of each of the 3-salt and 4-salt culture solu-
tions in different concentrations.   Data from Table 7.

investigation on this matter should be directed to the deter-
mination of the concentration of culture A_4 that can be consid-
ered optimum for this plant.

FLUCTUATIONS OF ABSORPTION

It is a well-known fact that processes occurring in the plant
body naturally vary or fluctuate in rate from time to time.
The rate of absorption of a culture solution by coco-palm roots
is not an exception to this rule.   It depends upon two sets of

conditions; those that occur inside and those that occur outside of the body of the plant. Among the important determining factors are the age and the health of the plant, its transpiring power, and transpiration. The last, in turn, depends upon the temperature of the air, humidity of the air, rain, wind velocity, and other factors. So, the rate of absorption indirectly depends upon the factors of weather just mentioned. Most of these factors naturally vary from hour to hour so that the record of absorption as here observed also fluctuated. The data in Table 10, which are graphed in fig. 5, bear this out. In this figure the
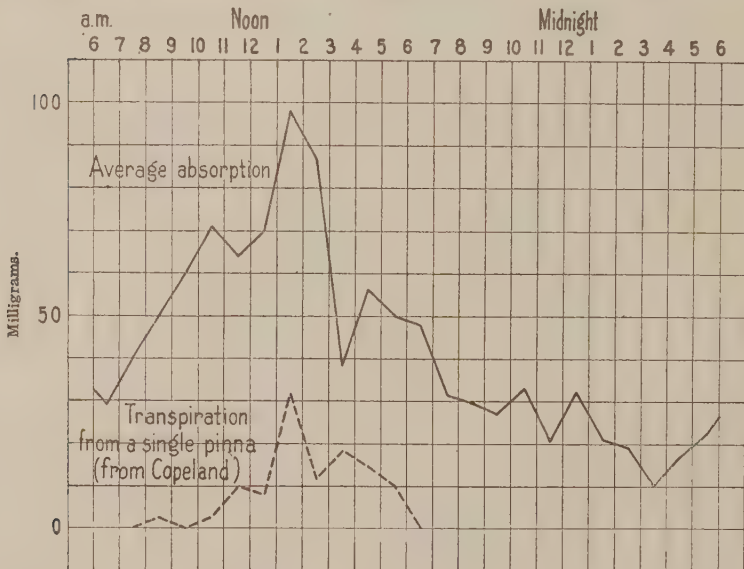
Fig. 5.   Showing average absorption by the four roots and transpiration from a single pinna as observed by Copeland.

records on transpiration obtained by Copeland(3) are also graphed for comparison. It should be admitted that for details the data on absorption and those for transpiration are not quite comparable, for they were taken at different times and not from the same tree. However, in one way comparison may be permissible, because the curves in fig. 5 represent what might be considered normal[2] absorption and normal transpiration.

[2] Normal refers to rate of transpiration or absorption observed during the ordinary or usual conditions of weather.

Judging from the general appearance of the curves it will be quite safe to say that there is a very close correlation between absorption and transpiration. This is to be expected, as the coco tree is known to possess no tissue or organ for water storage. So that, if transpiration is increased (provided other conditions are normal), absorption is also most likely to increase, or vice versa. The most rapid absorption took place during the first two or three hours after noontime. Copeland found these hours also the most favorable for rapid transpiration. As shown in Table 10, the average absorption per hour by a single root was 42.3 milligrams of solution A_1. This average is for the entire twenty-four hours. If night hours were to be excluded a much higher figure would be obtained. The highest record shown in this table is 97.5 milligrams per hour per root. Even assuming that a full-grown coco palm has 8,000 roots, the total absorption of a complete solution A_4 in a day by a tree would be only 18.73 liters. A more reliable record, however, would be about 16 liters. The computation, as Copeland made it, is based on 6,000 roots to a full-grown coco palm.

However, Copeland obtained a higher rate of absorption than this. From the conclusion derived from his results, Copeland reports that a coco palm can absorb 24 liters (computed) of water every day. Therefore, there is a discrepancy of about 6 liters. This discrepancy is somewhat hard to account for. It might be due to difference in the trees used, to location of the plantations, or to the kind of solution. The first two conditions could not be duplicated here, but the last was possible.

On November 26, 1922, at 6 a. m., 0.1 normal potassium nitrate solution was supplied to four roots of a coco palm. The results obtained are recorded in Table 11.

TABLE 11.—*Absorption of potassium nitrate solution by four roots of a coco palm.*

Root No.	November 26.		November 27.
	12 noon.	6 p. m.	
	g.	*g.*	*g.*
I	0.565	0.570	0.250
II	0.900	1.240	0.195
III	0.650	1.250	1.100
IV	0.735	1.085	0.200

Rain fell during the night of November 26. This was responsible for the low absorption on November 27.

Considering the absorption during the first twelve hours, we find that each root absorbed an average of 1.749 grams of the solution. This rate will give us about 3.6 grams for twenty-four hours, if it is to be assumed (although incorrectly) that the rate of absorption during the night hours and during the day hours was the same. Assuming further that a coco palm has 6,000 roots, then the total amount of the solution to be absorbed would be 21.6 liters; if 8,000 roots, the absorption by the tree in one day would be 28.8 liters. It appears that the single-salt solution (KNO_3) was more readily absorbed than was the 3-salt or the 4-salt culture solution. However, as was pointed out, it should be admitted that except in a well-balanced complete culture solution rapid absorption can never offer a maximum beneficial effect to the plant. Therefore, the 0.1 normal solution of potassium nitrate, although apparently more readily absorbed than was the complete solution A_4, cannot supply the plant with all the elements essential for its normal development, as the latter (A_4) does. Hence, hereafter 16 liters instead of 24 should be considered as the most likely maximum absorption of a complete solution in one day by a fairly good-sized full-grown coco palm.

Although all the factors in the environments of the coco palm have more or less a direct influence on absorption of solution by roots, nevertheless the data on hand seem to show that the so-called evaporating power of air plays the most important rôle. This one factor, although comparatively new to the science of plant physiology, is recognized as being very significant. It is the expression of the sum total of all other factors tending to promote the evaporation of water from a free surface or from the body of the plant.

As shown in fig. 6, the curve for the evaporating power of the air found by Trelease[10] agrees fairly with the curve of average hourly absorption of solution by the roots. This suggests that, provided soil moisture is abundant, the growing of the palm should prove successful, even in places where the drying influence of the air is great. Hitherto the palm has been generally grown in places where drought or a pronounced dry season does not exist, but the fact just brought out seems to confirm the belief of many interested in coconuts, that irrigation should be resorted to in time of drought.

The graphs in fig. 6 further show that the rate of absorption is in inverse ratio to the apparent pinna width. Therefore, the
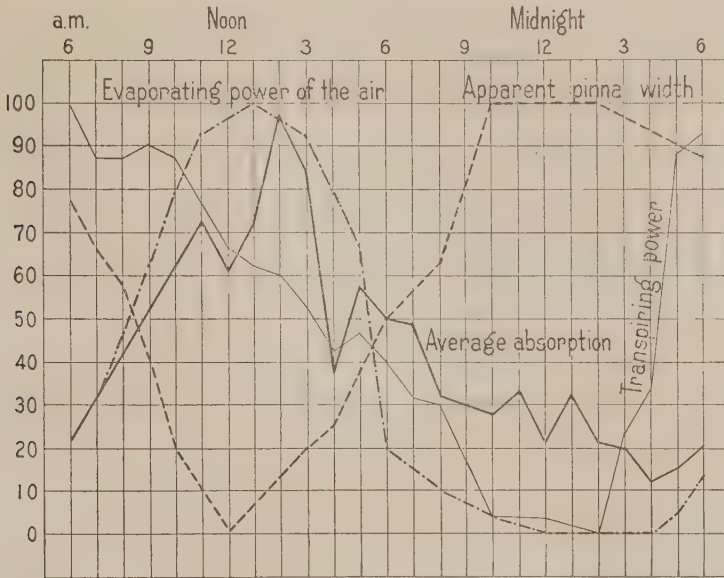
FIG. 6. Showing the transpiring power, apparent pinna width, and evaporating power of the air, as obtained by Trelease, and average hourly absorption from four roots.

latter might be employed in rough determination of the rate of absorption. A wide-open pinna would indicate that water or mineral solution is rapidly entering the root, or vice versa. However, precautions should be observed to make the interpretation only when several apparent pinna-width readings shall have been made, for it is somewhat evident that one or two hourly readings may not be sufficient.

The influence of environment on absorption may further be seen from the data given below, taken from the mass of data or figures collected during the progress of this study. The conditions of weather observed are given briefly in Table 12.

TABLE 12.—*Conditions of weather.*

Factor observed.	Rainless days.	Days with rain.
Date of observation	February 8 to 26	November 9 to 27.
Rainfall	None	572.3 millimeters.
Wind velocity	3.79 miles per hour	3.39 miles per hour.
Cloudy days	4.5	13.5.
Evaporating power of air	226.0 cubic centimeters	55.7 cubic centimeters.
Insolation	86.6 cubic centimeters	8.5 cubic centimeters.
Mean temperature of air	26.6° C.	25.5° C.

The records on absorption are as shown in Table 13.

TABLE 13.—*Absorption on rainless and on rainy days.*

RAINLESS DAYS.

	February						Average absorption per root per day.
	8–11	11–14	14–17	17–20	20–23	23–26	
	g.	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*
Absorbed by 12 roots_____	30.8	50.3	32.8	35.8	35.9	34.9	
Average per root_____	2.6	4.2	2.7	3.0	3.0	2.9	1.0

RAINY DAYS.

	November						Average absorption per root per day.
	9–12	12–15	15–18	18–21	21–24	24–27	
	g.	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*
Absorbed by 12 roots_____	7.9	10.4	9.1	11.1	10.8	9.3	
Average per root_____	0.7	0.9	0.8	0.9	0.9	0.8	0.3

The last column of figures shows that the rate of absorption was 233.33 per cent more rapid during rainless days than during rainy days. As a rule, rainless and sunny days are followed by a clear sky, greater evaporating power of the air and of the sun, and a higher mean temperature of the air. Collectively, these factors were responsible for a more rapid absorption of the solution by the roots. Rain is, of course, needed to supply water to the roots, but in the present study water or solution for the roots was well supplied. The rôle that rain played in these experiments was to increase the humidity of the air. This, in turn, decreased the evaporating power of the air, which was largely responsible for rapid transpiration. Rapid transpiration, as certain graphs in fig. 6 show, is usually accompanied by a corresponding rapid absorption.

SUMMARY AND CONCLUSIONS

From the extensive mass of data on the absorption of salt solutions by the roots of the coco palm, and under the conditions of this study, it appears that the following generalizations may be made:

1. That, as was expected, the rate of absorption of the 3-salt and the 4-salt culture solutions varied according to the molecular proportions of the salts.

2. That the most rapid absorption of a complete culture solution from the 3-salt and the 4-salt types supplied to the coconut tree the largest number of molecules of the solutes. This is in accordance with Avogadro's law.

3. That the best culture solution (A_4) found had a concentration of 0.1536 gram-molecule (of all the salts taken together) per liter and was characterized by 1 part, each, of ammonium sulphate, monopotassium phosphate, and calcium nitrate, and 5 parts of magnesium sulphate. A similar culture solution but in much weaker concentration was also found by Espino(4) as good for the young rice plant.

4. That culture solution A_4 had ammonium sulphate in addition to the other three salts in E_3, the best in the 3-salt type. This difference may suggest that the addition of ammonium sulphate was responsible for the rapid absorption. It may suggest further, as Bacomo(1) found, that the plant is benefited by an application of the substance.

5. That the rate of absorption of A_4 gradually increased from the morning hours to between one and two o'clock in the afternoon. Thence, a gradual decrease was observed, with slight fluctuations, until early the next morning. This form of curve corresponds fairly well with the records of Copeland for transpiration of the pinna of the same plant. It is suggested, therefore, in the case of this plant, that transpiration may serve as an index of absorption, or vice versa.

6. That the apparent pinna width may also serve as a rough index of the rate of absorption. Contrary to expectation and under normal conditions, rapid absorption takes place when the pinna is somewhat closed. However, in one way this should really be expected, as there is an apparent deficit in water in the leaf when the latter is closed.

7. That the evaporating power of the air appears to be directly proportional to absorption. This fact may suggest the possibility of successful cultivation of the coco palm even in places where the drying power of the air is great, provided that soil moisture is liberally supplied.

8. That the rate of absorption during a period of sunny days was about 233 per cent (average) more rapid than during a period of rainy days. This was really to be expected, but a quantitative comparison has never hitherto been made.

9. That an absorption of 24 liters (computed) by a full-grown coco palm in one day, as reported by Copeland, was based

on the data of absorption of potassium nitrate, a solution that does not supply all the elements essential for normal growth, which elements the plant usually derives from the soil. The maximum absorption (computed) by a tree in one day, of the best complete culture solution tested, appears to be 16 liters only.

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ILLUSTRATIONS

NOTES ON JAPANESE LEPIDOPTERA AND THEIR LARVÆ: PART VII

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Of Dorking, England

TWO COLORED PLATES

HETEROCERA

CERURIDÆ

Genus FENTONIA Butler

Fentonia BUTLER, Trans. Ent. Soc. London (1881) 20.

Fentonia ocypete Bremer.

Plate 1, fig. 1, larva; fig. 2, food plant. Larva of *Fentonia ocypete* forma *japonica* Grünberg.

Japanese name, *hosoba-shachihoko.*

Harpyia ocypete BREMER, Bull. Acad. Pétersb. (1861) 481 (=*lævis* Butler); Lep. Ost-Sib. (1864) 44, pl. 5, fig. 1, ♂; OBERTHÜR, Étud. d'Ent. 5 (1880) 60, pl. 8, fig. 6, ♂; LEECH, Proc. Zool. Soc. London (1888) 644, No. 308; HAMPSON, Moths Brit. India 1 (1892) 148; KIRBY, Cat. Lep. Het. (1892) 562; STAUDINGER, Rom. Mém. Lép. 6 (1892) 343; LEECH, Trans. Ent. Soc. London (1898) 304, No. 117; STAUDINGER and REBEL, Cat. Lep. Pal. I (1901) 107, No. 790; MATSUMURA, Cat. Insect. Jap. 1 (1905) 35, No. 280; Thousand Insects of Japan [Zoku Nihon Senchū Dzukai (Jap.)] (1909) Suppl. 1, 69, No. 118, pl. 11, fig. 1, ♀; GRÜNBERG, Seitz's Macrolep. Faun. Pal. 2 (1912) 291, pl. 45*b*, ♂; MARUMO, Journ. Coll. Agr. Imp. Univ. Tokyo 6 (1920) No. 4, 314, No. 54, pl. 23, fig. 8, imago; fig. 27, larva; fig. 28, cocoon; fig. 29, pupa; pl. 27, fig. 2; pl. 29, fig. 3; pl. 33, fig. 7; text-figs. 19, 20.

Fentonia lævis BUTLER, Trans. Ent. Soc. London (1881) 20; Cist. Ent. 3 (1885) 129.

Fentonia ocypete forma *japonica* GRÜNBERG, Seitz's Macrolep. Faun. Pal. 2 (1912) 292, pl. 45*b*, ♀; MATSUMURA, Ōyō Konchūgaku [Practical Entomology] ed. 2 (1920) 712 (Jap.).

The larva figured (Plate 1, fig. 1) was taken in September, 1900 (figured, September 22), at Yoshino, Yamato Province, Honshu, on dwarf oak, Japanese name, *kunugi* (*Quercus serrata* Thunberg). This larva died, and I failed to breed the imago; but I have bred imagoes of *F. ocypete* from similar larvæ on

several occasions at Tokyo, Honshu. I identified these speci-
mens at the British Museum (Natural History) in 1909 as *F.
ocypete* Bremer=*lævis* Butler, but they are referable to the form
japonica Grünberg described in 1912.

Grünberg [1] remarks:

> The Japanese specimens evidently belong to a special form, which we
> call japonica *form. nov.* (45b). The markings are somewhat less prom-
> inent, the black streak on the median vein is absent, likewise the light
> brown colouring, which is replaced by a band-like, light grey, median
> area reaching from first double line to the apex of the cell.

I describe the larva from my artist's original figure as
follows:

Larva.—Length, about 39 millimeters. Head grayish, mar-
bled with dark streaks; thoracic segments light greenish yellow;
two violet-brown mediodorsal spots on segment 2 (counting
head as segment 1); a violet-brown mediodorsal bar lined with
white continues from these spots as far as segment 4; the bar
is broad at each extremity and attenuated in the center, being
shaped somewhat like a dumb-bell; from segment 4 to anus the
color is, more or less, violet-white, tinged dorsally here and
there with yellow and streaked with faint, violet lines and small,
yellow patches, the latter being more prominent dorsally on the
posterior segments; on segment 6 there commences a broad,
violet-brown, arrow-shaped, mediodorsal bar which radiates at
the base on both sides laterad; the arrowhead is centered with
a yellow, diamond-shaped mark; the violet lines and yellow
patches form a definite mediodorsal pattern on the posterior
segments.

The larva feeds on the two dwarf oaks, Japanese names,
ko-nara and *kunugi* (*Quercus glandulifera* Blume and *Q. serrata*
Thunberg). It is an example of procryptic colors affording
general protective resemblance. This is defined by Poulton [2]
as "concealment as a protection against enemies, effected by
colors which harmonize with the total artistic effects of the
immediate environment." It generally rests at full length on
the edge of a leaf when feeding and eats right through to the
midrib. When stretched out in this manner its presence is
very difficult to detect as the position in which the larva places
itself gives it the irregular outline of the faded edge of a leaf

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[1] Seitz's Macrolep. Faun. Pal. 2 (1912) 292.
[2] Vide Philip. Journ. Sci. § D 9 (1914), Table 1, facing page 248.

still tinged with a little green. The posterior segments represent the faded part of the edge and the green thoracic segments represent the tinge of green in the leaf.[3]

Local distribution.—Honshu, Musashi Province, Yokohama (*Pryer*); Tokyo, bred, June (*Wileman*): Shinano Province, Oiwake (*Pryer*): Yamato Province, Yoshino, May, June, August, September (*Wileman*): Shimotsuke Province, Nikko, July (*Wileman*). Kyushu, Bungo Province, Usuki (*Marumo*). Matsumura records this species from Honshu and Hokkaido.

Time of appearance.—Larva, August, September, October; imago, May to September. There are probably two broods each year according to Hirayama.[4]

General distribution.—Eastern Siberia, Amurland; Korea; Japan; northern India, Simla (*Grünberg*); Manchuria (*Matsumura*). Bremer's type of *F. ocypete* is from Ussuri, eastern Siberia, June (*Maack*). Butler's male type of *F. lævis* is from Yokohama (*Pryer*). There is only one male specimen of this species from India in the British Museum (Natural History); all the remaining specimens are from Japan. The Indian specimen comes from Sabathu, near Simla (about 4,000 feet), ex Harford collection. The series in the British Museum consists of four males and three females.

Genus CERURA Schrank

Cerura SCHRANK, Fauna Boica 2, 2 Abth. (1802) 155.

Cerura milhauseri Fabricius.

> Plate 1, fig. 3, larva;[5] fig. 4, food plant. In the British Museum (Natural History) this species is placed in the genus *Cerura*. Japanese name, *gin-shachihoko*.
>
> *Bombyx milhauseri* FABRICIUS, Syst. Ent. (1775) 577 (=*terrifica* Schiffermüller); SEPP, Beschouwing der Wond. Gods. 5 (1836) 149, pl. 39, figs. 1–2, larva; fig. 3, cocoon; fig. 4, pupa; fig. 5, imago ♂; fig. 6, imago ♀; LEECH, Proc. Zool. Soc. London (1888) 641, No. 288; KIRBY, Cat. Lep. Het. (1892) 595; LEECH, Trans. Ent. Soc. London (1898) 309, No. 128; STAUDINGER and REBEL, Cat. Lep.

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[3] *Cerura milhauseri* Fabricius is another example of this protective resemblance, vide footnote 13.

[4] Marumo, Journ. Coll. Agr. Imp. Univ. Tokyo 6 (1920) No. 4, 315.

[5] I failed to breed an imago from this larva so am unable to say whether it would have developed into typical *milhauseri* Fabricius or variety *umbrosa* Staudinger, but, as will be seen further on, the type *milhauseri* is, in Gifu, Mino Province, commoner than the "East Asiatic form," variety *umbrosa*.

Pal. 1 (1901) 107, No. 791; HOFMANN, Gross-schmett. Eur. Ed. A.
Spuler 1 (1901–1910) 93; 3 (1908) pl. 22, fig. 4, imago ♂; 4 (1910)
pl. 19, fig. 19a, larva; Schl. taf. fig. 49, ovum; BERGE, Schmett.
Buch. (Rebel) (1910) 103, No. 245, pl. 22, fig. 14b, imago ♂; fig.
14a, larva; GRÜNBERG, Seitz's Macrolep. Faun. Pal. 2 (1912) 292,
pl. 45a, ♂, ♀; NAGANO, Nawa's Insect World [Konchū Sekai (Jap.)]
20 (1916) 7, pl. 1, figs. 1–13, larva, pupa, imago ♂, ♀; MARUMO,
Journ. Coll. Agr. Imp. Univ. Tokyo 6 (1920) No. 4, 296, No. 25,
pl. 22, fig. 7, imago; pl. 27, figs. 11, 14; pl. 36, fig. 1; text-fig. 6.

Bombyx terrifica DENIS and SCHIFFERMÜLLER, Schmett. Wien (1775)
63; HÜBNER, Bomb. (1800) pl. 8, figs. 32, 33.

Hybocampa milhauseri var. *umbrosa* STAUDINGER, Rom. Mém. Lép.
6 (1892) 343; STAUDINGER and REBEL, Cat. Lep. Pal. 1 (1901)
107, No. 791a; MATSUMURA, Cat. Insect. Jap. 1 (1905) 35, No.
281; Thousand Insects of Japan [Zoku Nihon Senchū Dzukai
(Jap.)], suppl. 1, 74, No. 126, pl. 11, fig. 9 ♀; GRÜNBERG, Seitz's
Macrolep. Faun. Pal. 2 (1912) 292, pl. 45a, ♀; MATSUMURA, Ōyō
Konchūgaku [Practical Entomology] ed. 2 (1920) 713, pl. 45,
fig. 5, imago; fig. 5a, larva; fig. 5b, pupa [Jap.].

The larva figured (Plate 1, fig. 3) was taken in October, 1900
(figured, October 27), at Yoshino, Yamato Province, on dwarf
oak, Japanese name, *kunugi* (*Quercus serrata* Thunberg). This
larva died, and I failed to breed the imago. However, I bred
a female of the so-called east Asiatic and Japanese form *Cerura
umbrosa* Staudinger from a similar larva on June 6, 1894.

Grünberg[6] places *Cerura milhauseri* Fabricius and the form
umbrosa Staudinger in the genus *Hoplitis* Hübner (=*Hybocampa*
Lederer), which is preoccupied in Hymenoptera, Klug, 1897,
and he describes the larva of the genus *Hoplitis* as follows:

Larva almost naked, only clothed with very short, thin, but rather
dense hair, with 14 feet, the head large, flat, incised above and having
a rounded-rectangular outline. Thoracical segment 1 with 2 short obtuse,
lateral tubercules, abdominal segments 1–6 each with a dorsal process
ending in a sharp point, which is directed anad, the anterior process of
considerable length, with forked tip, the following ones decreasing in
size, on segment 8 a large vertical dorsal process with sharp point, as
well as 2 small lateral ones with the point directed backwards; the anal
feet replaced by 2 very short points. Pupa short and stout, the anal
end broadly rounded, vertex with a short pointed tubercle which is
employed in opening the cocoon. The latter oval, flat, of the grey colouring
of the tree-trunk to which it is fastened.[7]—Only one species is known
of this genus [namely, *Hoplitis milhauseri*].

[6] Seitz's Macrolep. Faun. Pal. 2 (1912) 292.

[7] Esper says the larva spins between leaves, but that its usual place
is on the bark of the food tree like *Cerura*.—Esper 3 (1782) 108, pl. 21
fig. 1, larva; fig. 3, pupa; fig. 4, imago ♂; fig. 5, ♂ var.

Grünberg [8] describes the larva of *Hoplitis* [=*Cerura*] *mil-hauseri* Fabricius as follows:

Larva pale yellowish green, minutely dotted with red, abdominal segments 3–7 with whitish red lateral markings and red tubercles. When at rest the apex of the abdomen is held erect. June to August on Oak, also on Elm, Poplar and Birch. Pupa dark brown. The flat cocoons, which are very difficult to perceive, are less hard than in *Cerura* and *Dicranura;* the cocoons are only easily found if they bear a hole, which is said to be made by a woodpecker having eaten the chrysalis; in many instances, however, the hole means simply the exit of the moth. The latter emerges in May or June, comes to the lamp, and rests by day about 1–2 yards above the ground on the trunks of old Oaks.

Kirby [9] gives a figure of the larva of *Hybocampa* [=*Cerura*] *milhauseri* Fabricius and describes it as follows:

Green, granulated with whitish with a broad pale brown stripe on the sides; there are small red points on the humps of segments 6 to 10, and a branch-like excrescence, divided above, on that of the 5th segment. It lives on oak in July and August, and the cocoons, which are very difficult to distinguish from the bark, are nearly always found hollowed out by woodpeckers.

Newman [10] also gives a figure of the larva of *Hoplitis terrifica* (not British) (=*milhauseri* Fabricius).

. The following description of the larva of *Cerura milhauseri* Fabricius is based upon my artist's original figure and notes taken from two larvæ bred by me at Tokyo in September and October, 1893.

Larva.—Head light brown; body olive-green; on segment 2 (counting head as segment 1) there are two minute, subdorsal, brown tubercles, or warts; a medial, dorsal, longitudinal, white line from segment 2 to segment 4; a subdorsal, longitudinal white line on each side from segment 1 to segment 5 where it runs upward obliquely and joins the base of the dorsal process on segment 5; on segment 5 there is a long, mediodorsal, brownish white process armed with triple apical spines, two of which point anad, the third points cephalad; similar, but shorter, dorsal processes on segments 6 to 10, inclusive, and on segment 12, all armed with paired apical spines; the processes on segments 7, 8, and 12 are the longest, but not one of them is as long as the process on segment 5; a short minute spine at the lateral

[8] Loc. cit.
[9] European Butterflies and Moths (1889) 137, pl. 30, fig. 7a (larva).
[10] British Moths (1869) 203, fig. 7.

angle of the anal segment; all these processes and spines are curved anad; the anal claspers on segment 13 are absent and are replaced, above the anal flap, by two very short spinous points projecting outward; segments 6 and 7 mottled at the base of the dorsal process with small, irregular, brown spots and streaks on a whitish green ground which extends two-thirds of the way toward the spiracles; segment 8 dorsally dark, and laterally light brown, speckled with white dorsally; this brown color extends two-thirds of the way toward the spiracles and also extends dorsally to segments 7 and 9, giving the appearance of a lateral, triangular patch with its base resting dorsally on segments 7 to 9 and blunted at the apex; segment 9 laterally mottled with yellow which edges exteriorly the brown triangular patch; the posterior half of segment 9, also the succeeding segments to segment 13, mottled more or less, especially segments 10 and 13, with minute yellow spots; small brown patches at the base of the processes on segments 10 and 12 and a few brown streaks on segment 13; an irregular, whitish, longitudinal, spiracular stripe from segment 6 to segment 11, interrupted at segments 7 and 11; spiracles white, ringed exteriorly with brown; legs and prolegs green; the larva elevates the anal segments in the same way as *Stauropus fagi* Linnæus and other species of the same genus. A comparison of the description of the larva of *Hoplitis* [=*Cerura*] *milhauseri* given by Grünberg and of *Hybocampa* [=*Cerura*] *milhauseri* given by Kirby with my description of the larva shows the following differences:

Comparison of Grünberg's description: The larva of *umbrosa* is, I believe, naked, not "clothed with very short, thin, but rather dense hair." I did not, however, make any note on this point. The dorsal processes of "abdominal segments 1 to 6" (segments 5 to 10) do not, in my figure, "end in a sharp point which is directed anad," but in paired spines which are directed anad. The "anterior process" (segment 5) has a "forked tip" which is directed anad, but it also has a third spine directed cephalad which Grünberg does not mention. On "abdominal segment 8" (segment 12) there is not a "large, vertical process with a sharp point," but there is a process with paired spines which is much shorter than the process on segment 5 and is, apparently, not much longer than the processes on segments 7 and 8. The larva is not "minutely dotted with red," but is dotted with yellow on certain segments. Abdominal segments 3 to 7 are not "marked with whitish-red lateral markings and red tuber-

cles," but segments 6 to 9 (abdominal segments 2 to 5) are marked with an irregular, deep and pale brown patch and spots, and the spiracles are white, ringed exteriorly with brown. Grünberg states that A. Seitz found the larva of *Hoplitis* [= *Cerura*] *milhauseri* Fabricius on the cork tree [11] in northern Africa and that this larva differs from European ones in the tips of the processes being lemon yellow instead of red. Kirby calls these tips pink and says that the larva has a pale brown stripe on the sides. In my figure these tips are apparently brown, but I did not make any note on this point. Neither Grünberg nor Kirby mentions dorsal and subdorsal, white, longitudinal stripes on segments 2 to 5, nor a white spiracular stripe.

Pupa.—The pupa is inclosed in a hard, oval cocoon affixed to oak trunks. I have also observed that these cocoons are seldom to be found intact, but this may be caused either by the emergence of the moth or by birds. The species certainly is not common in Japan and possibly the attacks of birds have something to do with its rarity.

Nagano, in an article [12] on *Hoplitis milhauseri* Fabricius and its variety *umbrosa* Staudinger from which I have translated excerpts as follows, states that—

both typical *milhauseri* and the variety *umbrosa* occur in Japan. *Umbrosa*, which is usually regarded as the East Asiatic form of *milhauseri*, is generally of a darker colour and the hind wings are grey. * * * I have not bred this moth continuously throughout the year so cannot speak with absolute certainty regarding its life history. However, the year before last [1914] I captured twenty seven males at the electric light between June 3 and June 24 and eighteen males from August 8 to August 18. From this I infer that in the vicinity of Gifu this species must certainly be double brooded. The larvæ which I have observed, taking them in the foregoing sequence, are those corresponding to the second brood, namely, those seen from September to October. They feed on *kuri* [Spanish or sweet chestnut, *Castanea vulgaris* Lamarck var. *japonica* de Candolle], *kunugi* [dwarf oak, *Quercus serrata* Thunberg], but in Europe they are said to feed on *kashi* [oak, *Quercus* sp.], *nire* [elm, *Ulmus* sp.] *kabanoki* [birch, *Betulla* sp.], *yamanarashi* [aspen, *Populus tremula* Linnæus] and other trees. When full grown the larva generally fastens its flattened, oval, brown cocoon to the bark of a tree. The exterior of the cocoon is besprinkled with minute shreds of bark and lichen which so harmonise with the appearance of its environment that it is difficult to distinguish it. The pupa hibernates inside the cocoon and the imago emerges at the commencement of the following June

[11] The late Doctor Chapman says that he often found the empty cocoons on cork trees in the Riviera, southern France.

[12] Insect World [Konchū Sekai (Jap.)] **20** (1916) 7, pl. 1, figs. 1–13.

* * *. The curious shape of the larva is for purposes of protective resemblance.[13]

Furthermore, if the larva is viewed from behind, the dorsal portion of the last segment is flattened and ends in two spines which gives it a striking resemblance to the face of an animal. Whenever it raises this last segment, on being attacked by another creature, these spines look exactly like a swollen chin so that they evidently seem to be provided as a means of evading a rear attack * * *. The variety [*umbrosa*] which is regarded as the East Asiatic form occurs in Ussuri, China, Japan (Hokkaido, Honshu). * * * I do not regard the relations of the type and variety [*umbrosa*] as being of a local nature. At Gifu both can be taken together. There is one female specimen of the variety [*umbrosa*] among the specimens of this laboratory which was taken in the woods near the town of Gifu on August 22, 1890, but it was damaged at the time of the Great Earthquake and only the wings of one side and the body remain. This is, without any doubt, a specimen of *umbrosa*, and, up to now, was the only one to be found in our laboratory collection. Since the year before last [1914], however, we have been able to obtain many more specimens which have been attracted to our electric light, all these have proved to be *typical* specimens and the fact that we have never taken a single specimen of the variety [*umbrosa*] with them is exceedingly strange. It is however a fact that both type and variety occur together.

The following notes by Chapman [14] on *Hybocampa milhauseri* (=*Cerura milhauseri* Fabricius) are so interesting that I think it advisable to incorporate them in this paper:

Among my earliest entomological ambitions was a desire to become acquainted with this insect, my interest being, I think, excited by Sepp's figure of the larva, and the Vernacular name which he gives it, the "Dragon." It is now possible to purchase the insect alive, and I have thus been enabled to learn something of it, and I find it so remarkable in several particulars as to much more than justify my curiosity. It is not really closely related to any of our Notodontas, but is nearest to the Ceruras with a suspicion of true *Notodonta* (*N. ziczac* and *N. drome-darius*). The egg is large, clay coloured and beautifully zoned, with a dull terracotta like surface, apparently free from any structural lines or markings,—really the structure is so much finer than in *Cerura* that a much higher power is needed to show it,—of a form not very different from that of *C. vinula*. The egg of *C. erminea* is so different from that of *vinula* that it is, perhaps, not safe to say that that of *H. milhauseri* is not also of a *Cerura* pattern. * * *

The young larva has grand lateral horns in front and a dorsal row; as he grows older the lateral ones disappear whilst the dorsal ones remain,

[13] Vide Chapman, The Entomologist 23 (1890) 91 and 203. From the notes of Chapman and Nagano it appears that the larva enjoys the advantages afforded by procryptic coloration which gives it a special protective resemblance. Vide Philip. Journ. Sci. § D 9 (1914) Table 1, facing page 248.—A. E. W.

[14] The Entomologist 23 (1890) 91.

though proportionately smaller. I do not propose to describe the larva, which of course, is well known, and to which no description without a figure can do justice; but till I saw it alive I could not understand why any larva should have such remarkably angular outlines, curiously conspicuous corners and humps. What the dark young larva resembles I have not ascertained, but by chance I one day brought in with their food so exact a resemblance of the full-grown larva, that there could not be any doubt as to the meaning of all its curious outlines and markings. This was a curled oak leaf, eaten and abandoned by a *Tortrix* (*viridana* ?) larva.

This particular leaf was in detail exactly imitated by the larva of *H. milhauseri*. There was a curled portion of leaf with the outline of the body of the larva, the netted green texture of the leaf like the small markings on the surface of the larva, a brown decayed mark or two like the larva has; the extremity was eaten off on lines following partly a rib, so as to imitate the truncate aspect the larva has, however viewed; whilst the secondary ribs of the leaf, being eaten between projected laterally from the roll just like the dorsal spines of the larva, and in about the same size and order; the tall one in the 5th segment; the dwindling ones in the 6th to 10th; and the taller bifid one on the 12th; this one resembling points from both edges of the leaf. Most curious, perhaps, of all, the little backward projecting points at the tips of the spines (or humps), apparently so superfluously complicated in the larva, were exactly represented in the leaf; the *Tortrix* larva, in eating the substance of the leaf between the secondary ribs, had eaten these down to some extent also, but stuck fast just at a tertiary branch, the small remaining portion of which precisely represented the backward process of the larval spine. I never met with another rolled leaf that happened in exact number, size, and position, to represent all the processes of the larva as this one did, but any rolled and abandoned leaf bore a very close resemblance to the larva.

The cocoon is the most *Cerura*-like phase of this insect; it is made on the bark of the tree; though rather rounder and not quite so flat, it is in favorable specimens very like a *Cerura* in similar locality. It differs, however, in several particulars. In its construction the larva first makes a silken net over itself at the site of the cocoon; this is so open and flimsy looking, and so close down on the larva, which is rolled together under it, that it is surprising how the larva can move about inside to continue the work, and how in doing so it does not tear it all to pieces. *Cerura* on the other hand (I have watched *bifida* and *bicuspis*), selects a place for its cocoon, and begins at what will be the tail of the cocoon by making what looks like its head, a little structure like the toe of a slipper, it pushes this end forward, working beneath it by loosening its attachments in front and pushing its head under, spinning a continuation of it; in this way it gets under and detaches from the surface any bits of lichen and loose fragments of bark, which thus adhere in precisely their natural positions to the surface of the cocoon, and so much help its concealment; and having in this way pushed the front of the cocoon forward to its place, it closes the hinder end, and begins the excavating process by which it obtains the materials to form the outer part of the cocoon of a sort of artificial bark. *H. milhauseri* gets to the surface of the cocoon some colouring matters or lichenous material from the surface

of the bark, and puts a little detached material round the margin of the cocoon to make it fit a little; but the face of the cocoon, instead of being like that of *Cerura*, an artificial bark, is almost pure silk of a dense gummy substance, such as I have seen *vinula* make under difficulties when he could get no wood to work with. *Milhauseri* only slightly smooths the bark beneath the cocoon and covers it with gummy silk. *Cerura* lies in a neatly excavated cavity in the bark with practically no silken lining. Partly by its original close structure, and partly by contraction as it matures, this cocoon fits the pupa more closely than any other cocoon I have met with, so that, combined with its dense horny texture, it is extremely difficult to open it without injuring the contained pupa.

This close fitting of the cocoon to the pupa is related to perhaps the most curious of all the facts I have observed in this species, that is, its method of emergence; which is, I think, perhaps the most remarkable of any of the many remarkable provisions in different Lepidoptera for the escape of the moth from its cocoon.

As the shortest way of describing this process, I will call it cutting out a lid with a sardine opener.[15] Cerura bursts an irregular lid, having first softened the place with some fluid, and in many instances the broken lid falls back for a time into its place; the lid is irregular in form, often in several pieces, just as accident decides; but *milhauseri* marks out with his sardine-opener an exact definite lid, of which there is no trace or indication in the construction of the cocoon, and continues cutting on this exact line until the lid is set free. This lid is of oval shape, but with the anterior margin more rounded than the posterior. There is something more to be learnt about the action of this sardine-opener than I have yet ascertained, but I can give a few more particulars. First, as to the implement itself. In the pupa, just in front of the eyes and between the bases of the antennæ, is a deep pit, having at the bases of the antennæ, on either side, a sharp margin, almost a horn, stretching up from below; from the mouth region towards the pit, is a flat surface slightly furrowed and wrinkled, and terminating at the front margin of the deep pit (though one would say at first sight in the middle of it), in a straight spine projecting well beyond the general surface of the pupa, sharply pointed and polished; a slight ridge stretches back from the spine through the pit, and fades out on to the surface of the pupa, so that the pit might be described as a double furrow, stretching from before backwards. This spine is the sardine-opener, and by a lateral rotatory movement of the pupa which obtains its fulcrum from the tightness with which it is grasped by the cocoon, it traverses over and over again the outlines of the lid till it is cut through.

I have not seen this operation performed, for the reason that when you attempt to see it you stop it; but I have caught the creature actually at work, and can add this further fact, that the spine in some way

[15] The late Doctor Chapman in a letter addressed to me on June 15, 1920, says "Sardine-opener" is, perhaps, an unfortunate simile to use for the spine on the vertex of the pupa, since sardine-openers have at various times had various forms. In *milhauseri* the effective instrument is an upright spine that rather tears the softened silk than cuts it; the lid is just large enough for the moth to escape through.—A. E. W.

applies to its line of action a softening fluid, and it is the softened gum that it actually cuts or divides.

The fluid no doubt comes from the same mouth glands as in other cocoon-softening species, but the precise means by which it is guided by the spine I have not ascertained; whether the pit at its base has anything to do with it I cannot say, or whether this is a means of giving this portion of the pupa-case, which includes the eye-covers, a firm attachment to the moth; but very often it remains attached to the moth after the rest of the pupa-case has been pushed away backwards.

The imago is very delicate and easily rubbed, and such a specimen is a very disappointing representative of so curious a life-history; but a specimen in fine condition, from its delicate tints and unusual markings is very pleasing.

Imago.—Leech [16] remarks of Japanese and Chinese specimens of *milhauseri*:

> In all these specimens [three] the ground colour, especially of the secondaries, is darker than in the typical form and they are doubtless referable to var. umbrosa Staud.

I possess a male specimen from Japan, taken at Yoshino, Yamato Province, on June 21, 1901, which shows a light ground color, both in the fore and hind wings, thus approaching the typical form of *milhauseri* Fabricius. It compares well with some European examples in the British Museum (Natural History) series. Grünberg remarks that—

> In the East-Asiatic form, umbrosa Stgr. (45a), the whole outer half of the forewing is strongly darkened to the costal margin. Japanese specimens also are darker than European ones.[17] Egg pale brownish, with violet ring below pole.

Staudinger [18] described his variety *umbrosa* from a single male specimen from Askold Island, eastern Siberia and Grünberg calls this dark variety "the East Asiatic form." It is abundantly evident from Nagano's observations that in Gifu, Mino Province, Japan, the typical form of *milhauseri* Fabricius is much commoner than the variety *umbrosa* which is scarce. Therefore, as far as Japan is concerned it would seem that *umbrosa* can scarcely be called "the East-Asiatic form," but that it should merely be called a variety of the typical form of *milhauseri* Fabricius.

[16] Trans. Ent. Soc. London (1898) 309.

[17] Not always. I have a specimen fairly typical and vide Nagano's remarks, antea, page 82. Apparently, the European form is predominant at Gifu and variety *umbrosa* very scarce.—A. E. W.

[18] Rom. Mém. Lép. 6 (1892) 343.

There are three females of the form *unbrosa* Staudinger from Japan in the British Museum collection (Natural History) but no typical specimens. These are the specimens alluded to by Leech above, ex collection Pryer. They have dark hind wings, in fact very much darker than five males from Yoshino, Yamato Province, in my collection. There is also one female specimen in the British Museum collection from Berlin, Europe, the forewings of which are far darker than in any Japanese specimen.

Local distribution.—Honshu, Sagami Province, Oyama (*Pryer*) : Musashi Province, Tokyo, June bred (*Wileman*) ; Yokohama (*Manley*) : Yamato Province, Yoshino, June, August (*Wileman*) : Mino Province, Gifu, June, August (*Nagano*). Matsumura records the variety *umbrosa* Staudinger from Hokkaido and Honshu. The female specimen bred by me at Tokyo, in June, is a typical *umbrosa*.

Time of appearance.—Larva, September and October; imago, June, July?, August. Double-brooded. Matsumura states that *Hoplitis* (*Cerura*) *milhauseri* Fab. var. *umbrosa* Stgr. is double-brooded. The first brood appears in June and the second brood in August.

General distribution.—*Hoplitis* [=*Cerura*] *milhauseri*. Distributed in central and southern Europe, but everywhere rare, not found in England; Spain, Dalmatia, countries around the Black Sea; also in northern Africa (*Grünberg*).

Form *umbrosa* Staudinger; eastern Siberia, Amurland; western China; Japan (*Grünberg*). Manchuria (*Matsumura*).

Genus **LOPHOCOSMA** Staudinger

Lophocosma STAUDINGER, Rom. Mém. Lép. **3** (1887) 222.

Lophocosma atriplaga Staudinger.

Plate 1, fig. 5, larva; fig. 6, food plant; fig. 7, head.

Japanese name, *kurosuji-shachihoko*.

Notodonta (*Lophocosma*) *atriplaga* STAUDINGER, Rom. Mém. Lép. **3** (1887) 220, pl. 12, fig. 8, ♂; LEECH, Proc. Zool. Soc. London (1888) 641, No. 287; GRAESER, Berl. ent. Zeit. (1888) 139 (larva); KIRBY, Cat. Lep. Het. (1892) 606; STAUDINGER, Rom. Mém. Lép. **6** (1892) 347; LEECH, Trans. Ent. Soc. London (1898) 311, No. 138; STAUDINGER and REBEL, Cat. Lep. Pal. **1** (1901) 107, No. 797; MATSUMURA, Cat. Insect. Jap. **1** (1905) 35, No. 284; GRÜNBERG, Seitz's Macrolep. Faun. Pal. **2** (1912) 294, pl. 46c, ♀?; MARUMO, Journ. Coll. Agr. Imp. Univ. Tokyo **6** (1920) No. 4, 299, No. 30, pl. 22, fig. 12, imago; pl. 27, fig. 9; pl. 28, fig. 11; pl. 33, fig. 3; text-fig. 9; MATSUMURA, Thousand Insects of Japan [Shin Nihon Senchu Dzukai (Jap.)] (1921) Additamenta 4, 774, No. 806, pl. 57, fig. 1, ♂.

The larva figured (Plate 1, fig. 5) was taken in August, 1902 (figured, September 27), at Hakodate, Oshima Province, Hokkaido (Yezo), on a tree of which the name was not noted by me. A female imago was bred from this larva on June 21, 1903, and three male imagoes were also bred on June 12 and 18, 1903, from larvæ taken at the same time and place and on the same tree. Graeser [19] gives the following notes on *Notodonta atriplaga* Staudinger:

At Chab. [Chabarofka] I found the larva several times on *Corylus mandschurica* Maxim. At Wlad. [Wladiwostock] the larva was also not rare but was found here on *Ostrya*. I also received this species from Blag. [Blagoweschtschensk].[20]

The full grown green larva looks just like a small larva of *Sphinx ligustri;* it has like the latter white and red-violet oblique stripes on the sides, two black, longitudinal streaks on the head and on the eleventh segment a somewhat bent, yellow and black hornlike protuberance ("zapfen"). It is full grown at the end of July and commencement of August; the pupa hibernates; moth in June.

I describe the larva from my artist's original figure as follows:

Larva.—Length, about 45 millimeters. Head whitish green, lined with black; mandibles black; body green, naked; darker green mediodorsal and subdorsal longitudinal stripes; spiracles black; a red spot on segments 5 and 6 just below each segmental spiracle; a faint, interrupted, yellowish spiracular line; four short, reddish, oblique stripes edged with yellow and directed toward the head obliquely upward and backward, these stripes commence on a line with the spiracles and reach halfway down the prolegs on segments 7 to 10; a longer, reddish stripe extending obliquely from the spiracle on segment 11 to end of anal claspers; anal flap edged with black; legs ochraceous; prolegs green, tipped with reddish; short caudal horn on segment 12, reddish at base and tipped with black.

Pupa.—Black, shining, smooth, inclosed in a flimsy cocoon spun in leaves of the food plant.

Local distribution.—Honshu, Sagami Province, Miyanoshita, June (*Wileman*): Shimotsuke Province, Nikko, August (*Wileman*): Musashi Province, Tokyo (*Marumo*). Hokkaido, Oshima Province, Hakodate, June (*Wileman*). Matsumura records this species from Hokkaido and Honshu.

Time of appearance.—Larva, August; imago, June and August.

[19] Berl. ent. Zeit. (1888) 139.
[20] These three places are in Amurland, eastern Siberia.—A. E. W.

General distribution.—Eastern Siberia, Amurland, southern Ussuri; Japan, often not rare (*Grünberg*); Korea (*Marumo*); Manchuria (*Matsumura*).

Genus BRACHIONYCOIDES Marumo

Brachionycoides MARUMO, Journ. Coll. Agr. Imp. Univ. Tokyo **6** (1920) No. 4, 361.

Brachionycoides atrovittatum Bremer.

Plate 1, fig. 8, larva; fig. 9, food plant.
Japanese name, *kubiwa-shachihoko.*
Asteroscopus atrovittatus BREMER, Bull. Acad. Pétersb. **2** (1861) 483; Lep. Ost-Sib. (1864) 46, pl. 5, fig. 4; KIRBY, Cat. Lep. Het. (1892) 562; LEECH, Trans. Ent. Soc. London (1898) 304, No. 116; STAUDINGER, Cat. Lep. Pal. **1** (1901) 109, No. 813; MATSUMURA, Cat. Insect. Jap. **1** (1905) 36, No. 295; Thousand Insects of Japan [Zoku Nihon Senchū Dzukai (Jap.)] (1909), Suppl. **1**, 77, No. 130, pl. 11, fig. 13, ♀; WILEMAN, Trans. Ent. Soc. London (1911) 284, No. 195; GRÜNBERG, Seitz's Macrolep. Faun. Pal. **2** (1912) 299, pl. 45*f*, ♂?
Destolmia insignis BUTLER, Trans. Ent. Soc. London (1881) 19; LEECH, Trans. Ent. Soc. London (1898) 310, No. 131.
Notodonta toddii HOLLAND, Trans. Am. Ent. Soc. **21** (1889) 73; LEECH, Trans. Ent. Soc. London (1898) 311.
Brachionycoides atrovittatum MARUMO, Journ. Coll. Agr. Imp. Univ. Tokyo **6** (1920) No. 4, 317, No. 57, pl. 22, fig. 9, imago; pl. 25, fig. 3; pl. 27, fig. 13; pl. 29, fig. 6; pl. 33, fig. 1; text-fig. 21.

The larva figured (Plate 1, fig. 8) was taken at Hakodate, Hokkaido, in September, 1902 (figured, September 22), on a species of maple, Japanese name, *itaya-kaede* (*Acer pictum* Thunberg var. *mono* Maximowicz). This larva died and consequently no imago developed, but a female of *Brachionycoides atrovittatum* Bremer was bred from a similar larva taken on July 6, 1903, at Hakodate.

Pupa.—Smooth, shining black.

I describe the larva from my artist's original figure as follows:

Larva.—Length, about 50 millimeters. Head green; dorsum whitish; tending to green in the spiracular region; a waved, yellow, subspiracular line, which is prominently edged with black on segments 2 to 11; legs dark ochraceous; prolegs green, shaded with black extending from the edging of the subspiracular, yellow stripe; anal claspers black; segmental sutures well defined and more or less tinged with yellow.

Local distribution.—Honshu, Musashi Province, Yokohama and Tokyo (*Holland, Pryer, Matsumura*), June and August (*Wileman*): Yamato Province, Yoshino, June, August (*Wile-*

man) : Kii Province, Nachi (*Marumo*) : Shimotsuke Province, Nikko, July (*Wileman*) : Sagami Province, Miyanoshita, June (*Wileman*). Hokkaido (Yezo), Oshima Province, Tobetsu and Junsai Numa, July and August (*Wileman*). Matsumura records this species from Honshu and Hokkaido.

Time of appearance.—Larva, September; imago, June to August.

General distribution.—Japan; eastern Siberia, Ussuri (*Grünberg*) ; Manchuria (*Matsumura*).

The type of *Asteroscopus* (*Brachionycoides*) *atrovittatus*, sex?, was taken by Maack in the Lower Ussuri, eastern Siberia, in June. The type of *Destolmia insignis*, female, was taken at Tokyo by Fenton. The type of *Notodonta toddii*, a female, was taken at Yokohama.

In the British Museum (Natural History) this species is placed under Genus *Microphalera* Butler, but Marumo has founded a new genus for its reception in his revision of the Notodontidæ of Japan, Corea, and Formosa.

Genus **DRYMONIA** Hübner

Drymonia HÜBNER, Verz. Schmett. 144 (1822).

Drymonia lineata Oberthür.

Plate 2, fig. 1, larva; fig. 2, food plant.

Japanese name, *shima-shachihoko.*

Notodonta lineata OBERTHÜR, Étud. d'Ent. 5 (1880) 61, pl. 2, fig. 7, ♂; LEECH, Proc. Zool. Soc. London (1888) 639, No. 277; STAUDINGER, Rom. Mém. Lép. 6 (1892) 356; LEECH, Trans. Ent. Soc. London (1898) 310, No. 132; STAUDINGER and REBEL, Cat. Lep. Pal. 1 (1901) 108, No. 803; MATSUMURA, Cat. Insect. Jap. 1 (1905) 35, No. 287; GRÜNBERG, Seitz's Macrolep. Faun. Pal. 2 (1912) 296, pl. 45d, ♂.

Pheosia octofasciata MATSUMURA, Thousand Insects of Japan [Zoku Nihon Senchū Dzukai (Jap.)] (1909) Suppl. 1, 54, pl. 9, fig. 9, imago, ♂.

Drymonia lineata MARUMO, Journ. Coll. Agr. Imp. Univ. Tokyo 6 (1920) No. 4, 337, No. 91, pl. 22, fig. 21, imago.

The larva figured (Plate 2, fig. 1) was taken in July, 1902 (figured, July 19), at Hakodate, Oshima Province, Hokkaido, on *sennoki* (*Acanthopanax ricinifolium* Siebold and Zuccarini), also known as *hari-giri*. It pupated on July 25, 1902, and a male imago emerged on August 7, 1902. I describe the larva from my artist's original figure as follows:

Larva.—Length, about 41 millimeters. Head grayish white faced with green; body bluish green; broad, mediodorsal and sub-

dorsal, yellow stripes; two minute, black spots on each segment of dorsum on the edge of the subdorsal, yellow stripes; laterally paler; ventrum whitish; legs, prolegs, and claspers greenish white.

Local distribution.—Honshu, Shinano Province (*Marumo*). Hokkaido, Oshima Province, Tobetsu (June, July, August), Hakodate (August), Junsai Numa (August) (*Wileman*): Ishikari Province, Jozankei, June to August (*Wileman*), Sapporo (*Marumo*). Matsumura records the species from Hokkaido.

Time of appearance.—Larva, July; imago, May to August.

General distribution.—Eastern Siberia, southern Ussuri, Japan (*Grünberg*).

In the British Museum (Natural History) this species is placed under *Notodonta* but Marumo, in his revision of the Notodontidæ of Japan, Corea, and Formosa, transfers it to *Drymonia* Hübner.

Oberthür's type was, apparently, one of two males taken in May and June, 1878, on Askold Island, eastern Siberia.

Genus HYPERÆSCHRA Butler

Hyperæschra BUTLER, Ann. & Mag. Nat. Hist. V **6** (1880) 65.

Hyperæschra biloba Oberthür.

Plate 1, fig. 10, larva; fig. 11, head; fig. 12, food plant.

Japanese name, *kunugi-shachihoko.*

Drymonia biloba OBERTHÜR, Étud. d'Ent. **5** (1880) 63, pl. 8, fig. 1, ♂; STAUDINGER, Rom. Mém. Lép. **6** (1892) 358; STAUDINGER and REBEL, Cat. Lep. Pal. **1** (1901) 109, No. 287; WILEMAN, Trans. Ent. Soc. London (1911) 295, No. 216; GRÜNBERG, Seitz's Macrolep. Faun. Pal. **2** (1912) 302, pl. 45*d*, ♂.

Hyperæschra biloba MARUMO, Journ. Coll. Agr. Imp. Univ. Tokyo **6** (1920) No. 4, 318, No. 58, pl. 22, fig. 23, imago, ♀; pl. 29, fig. 5; pl. 36, fig. 6.

Hyperæschra basalis Matsumura (? nec Moore) Thousand Insects of Japan [Shin Nihon Senchū Dzukai (Jap.)] Additamenta **4** (1921) 798, No. 831, pl. 58, fig. 8, ♂, ? nec Moore.

The larva figured (Plate 1, fig. 10), was taken in August, 1902 (figured, August 22), at Hakodate, Oshima Province, Hokkaido, on *hannoki* (*Alnus japonica* Siebold and Zuccarini), also known as *harinoki* and *yachihannoki.* No imago was bred from this larva as it died, but a male imago was bred on June 22, 1903, from a similar larva taken during 1902. I describe the larva from my artist's original figure as follows:

Larva.—Length, 49 millimeters. Head green lined with black; body green; a mediodorsal, pink stripe broadly edged on

both sides with white; spiracles white, ringed with black; seven lateral, pink stripes, broadly edged with white, directed obliquely toward the head upward and backward, from segments 5 to 12; similar small dashes on segments 3 and 4 directed obliquely anad, upward and backward; legs ochraceous, prolegs, claspers, and ventrum green.

Pupa.—Black, smooth and glossy; inclosed in a frail cocoon spun among leaves of the food plant.

Local distribution.—Honshu, Yamato Province, Yoshino, July, August (*Wileman*): Shimotsuke Province, Nikko, August (*Wileman*); Kii Province and Kaga Province (*Marumo*); Yamashiro Province, Kyoto, June (*Matsumura*). Hokkaido, Oshima Province, Hakodate and Junsai Numa, June, July (*Wileman*); Ishikari Province, Tobetsu, July (*Wileman*).

Time of appearance.—Larva, August; imago, June to August.

General distribution.—Eastern Siberia, southern Ussuri; Japan (*Grünberg*). Type of *Drymonia biloba,* male, from Askold Island, eastern Siberia.

In the British Museum (Natural History) this species is placed under the genus *Hyperæschra* Butler and also by Marumo in his revision of the Notodontidæ of Japan, Corea, and Formosa.

The following notes on three very closely allied species of the genus *Hyperæschra* may be of value for determining their respective merits as distinct and valid Japanese species.

Hyperæschra basalis Moore.

> *Notodonta basalis* MOORE, Proc. Zool. Soc. London (1865) 813.
>
> *Hyperæschra basalis* HAMPSON, Moths India 1 (1892) 165, text-fig. 101, ♂; MATSUMURA, Thousand Insects of Japan [Shin Nihon Senchū Dzukai (Jap.)] Additamenta 4 (1921) 798, No. 381, pl. 58, fig. 8, ♂ (*kunugi-shachihoko*) (? nec Moore=? *biloba* Oberth.).

There are five males of this species in the British Museum (Natural History) from Sikkim and Darjiling, India. The species differs in color, expanse, bipectination of antennæ, and the angulation of postmedial line of forewing from *Hyperæschra biloba* Oberthür with which it has been associated by Matsumura. The antennæ of *basalis* Moore male are bipectinate for the proximal three-fourths length of the shaft while in *biloba* Oberthür they are bipectinate almost to the apex of the shaft. *Hyperæschra basalis* Moore has the basal half of forewings very much darker in color (inside the postmedial line); the expanse is about 50 millimeters against a maximum of 46

millimeters for *biloba* Oberthür. Matsumura, in his last work, under "*Hyperæschra basalis* Moor [e] (=*biloba* Oberthür) Japanese name kunugi-shachihoko," sinks *biloba* Oberthür in *basalis* Moore, of which he gives a figure. This figure seems to compare fairly well with Hampson's figure of *basalis* Moore, from which it may perhaps have been copied, and also with specimens of that species in the British Museum collection, but it may possibly have been taken from a Japanese specimen in the possession of Matsumura. If so, and if the antennæ are bipectinate for the proximal three-fourths of the shaft, then *basalis* Moore should be recognized as a distant Japanese species.

Hyperæschra basalis Moore and *biloba* Oberthür are, therefore, two quite distinct species as an examination of the series of the former in the British Museum (Natural History) proves and are separated in that collection. I have alluded to the resemblance of the two species.[21]

Hyperæschra tusa Swinhoe.

> *Hyperæschra tusa* SWINHOE Ann. & Mag. Nat. Hist. VII **19** (1907) 207.

Of this species there is one specimen only in the British Museum (Natural History), the male type from Japan, and this species is placed between *Hyperæschra basalis* Moore and *H. biloba* Oberthür. It will, however, I think, be eventually proved to be merely a large, darker form of *H. biloba* Oberthür but, owing to the lack of sufficient material, must, for the present, be left as a distinct species. It expands 51 millimeters; the color is rather darker than that of *biloba* as figured by Oberthür; antennæ the same as in *biloba*, but the angulation of the postmedial line is rather different as at vein 1 it is more excurved and from veins 1 to 4 more incurved. As this species has not hitherto appeared in any catalogue of Japanese Heterocera I append Swinhoe's original description herewith.

♂. Dark grey: forewings with more than the basal half much darker than the outer portions, limited by a thick black line from the costa at two-thirds to vein 4, then curved inwards to vein 1, then obliquely inwards to the production at the middle of the hinder margin, where it is very thick; a black mark just inside this on the margin, and two black angles between them, forming the commencement of a transverse line; an indistinct, grey, transverse, sinuous band in the disc: hind wings grey, without markings;

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[21] Trans. Ent. Soc. London (1911) 295.

cilia of fore wings ochreous grey, of hind wings pale grey, both with darker patches: antennæ, body, legs and wings on the underside pale grey, uniform in colour, a slightly darker medial band across both wings. Expanse of wings 2 inches.

Japan (*Schaus*) (type in B. M.).

Allied to *H. basalis*, Moore.

Hyperæschra biloba Oberthür.[22]

One male specimen in British Museum (Natural History) from Miyanoshita, Sagami Province; Honshu, August 27, 1910, expanse 42 millimeters. In my collection I have eight males measuring 42 to 47 millimeters as follows: One male which represents the male imago bred on June 22, 1903,[23] and measures 44 millimeters agrees well in color, markings and angulation of the postmedial line with Oberthür's figure of *Drymonia biloba*,[24] which, he states in the text, was bred June 29, 1879, on Askold Island, eastern Siberia. In this specimen the postmedial line of forewing is just slightly more deeply incurved between veins 1 and 4 than in Oberthür's figure. Three males from Hokkaido, Oshima Province, Junsai Numa, July 25 and 29, 1902, (plains) and Ishikari Province, Tobetsu, July 7, 1902, (plains); three males from Honshu, Yamato Province, Yoshino (about ? 800 feet), expanse 42 millimeters, July 14, 1899, and August 15, 1894. Two of the latter specimens are rather smaller in expanse than the others and agree better in coloration with *tusa* Swinhoe than with Oberthür's figure but not in the angulation of the postmedial line. One male from Shimotsuke Province, Nikko, August 16, 1893. As previously remarked I think that *tusa* Swinhoe and *biloba* Oberthür will probably be found to be identical species with a modified angulation of the postmedial line of forewing in different individuals. Marumo[25] states that—

the angulation is modified among the sexes. In the male the postmedial line more deeply incurved between veins 1 and 4 than in the female, and the angulation at vein 1 acute, the space between the ante- and postmedial lines being broader.

Further material, breeding, and examination of genitalia are necessary before it can be satisfactorily decided whether *tusa* Swinhoe is the same species as *biloba* Oberthür. One of my specimens of *biloba* from Tobetsu July 7, 1902, approaches

[22] For synonymy and bibliography see antea, page 90.

[23] See antea, page 90.

[24] Oberthür, Étud. d'Ent. 5 (1880) 63, pl. 8, fig. 1, ♂.

[25] Journ. Coll. Agr. Imp. Univ. Tokyo 6 (1920) No. 4, 318, No. 58.

tusa in expanse (47 millimeters), coloration, and angulation of postmedial line. As *Hyperæschra basalis* Moore is apparently not a Japanese species, the Japanese name of kunugi shachihoko given to it by Matsumura should be transferred to *Hyperæschra biloba* Oberthür.

Genus **SPATALIA** Hübner

Spatalia HÜBNER, Verz. bek. (1822) 145.

Spatalia ornata Oberthür.

> Plate 2, fig. 3, larva, green form; fig. 4, larva, violet-gray form; fig. 5, food plant; fig. 5a, imago, ♂. Larva of *Spatalia* (*Rosama*) *macrodonta* Butler.
>
> Japanese name, *hitogimboshi-shachihoko*.[26]
>
> *Ptilodontis ornata* OBERTHÜR, Étud. d'Ent. 10 (1884) 15, pl. 2, fig. 5, ♂; STAUDINGER, Rom. Mém. Lép. 6 (1892) 362; Cat. Lep. Pal. 1 (1901) 110, No. 834; LEECH, Trans. Ent. Soc. London (1898) 315; GRÜNBERG, Seitz's Macrolep. Faun. Pal. 2 (1912) 304, pl. 46f, ♂ ♀.
>
> *Spatalia ornata* MARUMO, Journ. Coll. Agr. Imp. Univ. Tokyo 6 (1920) No. 4, 291, No. 15, pl. 28, fig. 5; pl. 32, fig. 4.
>
> *Rosama macrodonta* BUTLER, Cist. Ent. 3 (1885) 127; LEECH, Proc. Zool. Soc. London (1888) 637, No. 267; Trans. Ent. Soc. London (1898) 315, No. 150; MATSUMURA, Cat. Insect. Jap. (1905) 37, No. 304; GRÜNBERG, Seitz's Macrolep. Faun. Pal. 2 (1912) 304 (no figure).
>
> *Spatalia ornata* Oberthür (part) MARUMO, Journ. Coll. Agr. Imp. Univ. Tokyo 6 (1920) No. 4, 291, No. 15.

Two forms of the larva (Plate 2, figs. 3 and 4) were taken at Yoshino, Yamato Province, Honshu, on *hagi* (*Lespedeza bicolor* Turczaninow). Form 1 (Plate 2, fig. 3), light green form, was taken in October, 1900 (figured, October 15). Form 2 (Plate 2, fig. 4), violet-gray form, was taken in November, 1900 (figured, November 2).

A male imago emerged on May 28, 1901, and another male imago, on June 9, 1901.

The imago of *Spatalia macrodonta* Butler apparently has never been figured by any author. I have figured it on Plate 2, fig. 5a, from a male specimen in my collection. I describe forms 1 and 2 from my artist's original figures as follows:

Form 1.—Length, about 27 millimeters. The larva is somewhat shrunken as it was preparing to pupate. Light green with a darker, mediodorsal line and a few short hairs; a yel-

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[26] No Japanese name has been given to this species by Matsumura; therefore, I name it as above.

lowish, spiracular line; spiracles black; legs grayish; prolegs green tipped with gray; on segment 12 a slight prominence which bears two, grayish, hairy, dorsal tubercles.

Form 2.—Length, 36 millimeters. Ground color pale violet-gray; head gray; a well-defined, mediodorsal, violet-gray stripe from segment 2 (counting head as segment 1); a mediolateral, violet-gray stripe, shaded beneath with light yellow, running from segment 2 to segment 12; a violet-gray, spiracular stripe, shaded below with broader yellow running from segment 2 to anus; spiracles black; ventrum, all legs, and anal segment violet-gray.

Pupa.—The pupa is inclosed in a frail cocoon, which was spun in a leaf of the food plant.

Imago.—I have a series of nine males and four females from Japan. In the males there is a silver marking situated at the base of vein 2. In one male this mark is practically obsolete; in three males it takes the form either of a small spot or a slender streak; in five males this spot, or streak, becomes enlarged to the shape of a triangular wedge and these specimens agree with the figure of *Ptilodontis ornata* Oberthür, in which it is large and a little larger than in my five male specimens.

In two females the silver mark is obsolete; in two others it is just faintly discernible as a slender streak. In the collection of the British Museum (Natural History) there are two males from Japan, including the type, and three females, one from Japan and two from Pekin, North China (female types).

The type male and the second male have a slender streak at vein 2.

The females have apparently no streak, but they are rather rubbed and it is therefore difficult to be quite certain about this.

Butler does not mention this silver marking in his descriptions of the type male and female, one from Japan, the other from China.

Marumo says: [27]

The silvery spot at the base of vein 2 of the forewing is much reduced in size or entirely absent in the female.

Although I have not examined the types of both *ornata* and *macrodonta* I can not find any specific distinction between them according to their original description.

[27] Journ. Coll. Agr. Imp. Univ. Tokyo **6** (1920) No. 4, 291, No. 15, pl. 28, fig. 5; pl. 32, fig. 4.

He therefore regards *Spatalia* (*Rosama*) *macrodonta* Butler as a probable synonym of *Spatalia* (*Ptilodontis*) *ornata* Oberthür. I strongly agree with this opinion. *Ornata* Oberthür is not represented in the collection of the British Museum (Natural History) either as a synonym of *macrodonta* Butler or as a separate species. This perhaps is not surprising as the family of the Ceruridæ (Notodontidæ) in the British Museum collection has been awaiting revision for some years. Grünberg,[28] although he quotes *Spatalia macrodonta* Butler in his text, gives no figure of it, but gives male and female figures of *Spatalia ornata* Oberthür. The male of *ornata* figured by Seitz, which has perhaps been copied from Oberthür's figure or type, differs chiefly from typical *macrodonta* in the triangular shape and much larger size of the silver marking. The female of *ornata*, however, figured by Seitz agrees remarkably well with a fresh, unrubbed, female specimen of *macrodonta* Butler in my collection. I consider that *macrodonta* Butler should be sunk in *ornata* Oberthür which has priority. The silver spot at base of vein 2 is in *macrodonta* evidently subject to much variation. Oberthür described and figured his species from one of four male specimens taken at Sidemi, Ussuri, eastern Siberia. The female of *ornata* Oberthür, as figured in Seitz, has no silver spot and in this respect agrees with the females of *macrodonta* in the British Museum collection and with two of my females.

Local distribution of Spatalia macrodonta Butler.—Honshu, Yamato Province, Yoshino, June, September, bred in June (*Wileman*): Shimotsuke Province, Nikko, July (*Wileman*). Kyushu, Hyuga Province, Shimo-shiiba, July (*Wileman*.) Matsumura records this species from Honshu only.

Marumo gives the local distribution of *Spatalia ornata* Oberthür as follows: Honshu, Shimosa Province; Kaga Province; Musashi Province, Tokyo and Yokohama. Shikoku Island, no localities given. Therefore, the species *Spatalia ornata* (including *macrodonta*) is found in the three islands of Honshu, Shikoku, and Kyushu.

Time of appearance.—Larva, October, November; imago, June and July (*Wileman*); August (*Marumo*).

General distribution.—Japan; northern China (Grünberg).

[28] Seitz's Macrolep. Faun. Pal. 2 (1912) 304.

Genus LOPHOPTERYX Stephens

Lophopteryx STEPHENS, Ill. Brit. Ent. Haust. 2 (1829) 26.

Lophopteryx saturata Walker.

Plate 2, fig. 6, larva; fig. 7, food plant; fig. 8, anal section, dorsal aspect.
Japanese name, *momiji-shachihoko*.[29]

Lophopteryx saturata WALKER, Cat. Lep. Het. 32 (1865) 415; OBER-
THÜR, Étud. d'Ent. 5 (1880) 66; BUTLER, Ill. Typ. Lep. Het. 6
(1886) 25, pl. 107, fig. 1; HAMPSON, Moths Brit. India 1 (1892)
166, fig. 102, ♂; STAUDINGER and REBEL, Cat. Lep. Pal. 1 (1901)
110, No. 842; GRÜNBERG, Seitz's Macrolep. Faun. Pal. 2 (1912) 307,
pl. 46*h;* WILEMAN, Trans. Ent. Soc. London (1911) 295; MARUMO,
Journ. Coll. Agr. Imp. Univ. Tokyo 6 (1920) No. 4, 301, No. 33.

Lophopteryx hoegei GRAESER, Berl. ent. Zeit. (1888) 143 (larva);
STAUDINGER, Rom. Mém. Lép. 6 (1892) 360; STAUDINGER and REBEL,
Cat. Lep. Pal. 1 (1901) 110, No. 842*a;* GRÜNBERG, Seitz's Macrolep.
Faun. Pal. 2 (1912) 308 (no figure); MARUMO, Journ. Coll. Agr.
Imp. Univ. Tokyo 6 (1920) No. 4, 301; No. 33, pl. 23, fig. 22, ♂.

The larva figured (Plate 2, fig. 6), was taken in October, 1902
(figured, October 7), at Hakodate, Oshima Province, Hokkaido,
on a species of maple, Japanese name, *itaya-kaede,* also known
as *o-tsutamomiji* (*Acer pictum* Thunberg). The larva died and
no imago was bred from it, but I bred three female imagoes of
Lophopteryx saturata Walker from similar larvæ at Hakodate
on September 2, 1902, and July 7, 1903.

In the British Museum (Natural History) collection there are
fifteen male specimens of *Lophopteryx saturata* Walker but no
females, all with one exception from India (Darjiling, Bengal
Province, about ? 7,000 feet) and Sikhim (Pilcher, May, 1896,
7,000 feet; F. Möller, August and September, 1909). The one
exception is from Japan, unlocalized (B. Bristowe, 1901). This
specimen seems to be nearer typical *hoegei* Graeser than *satu-
rata* Walker. In my collection I have four males and seven fe-
males of *saturata* Walker and variety *hoegei* Graeser taken, as
noted in the local distribution on page 100, in June to
September. The three females[30] bred at Hakodate on Sep-
tember 2, 1902, and July 7, 1903 are, I think, referable to *sa-
turata* Walker, not to variety *hoegei* Graeser. The type
of *Lophopteryx saturata* Walker comes from Darjiling (about

[29] No Japanese name has been given to this species by Matsumura:
therefore, I name it as above.
[30] Vide preceding paragraph.

? 7,000 feet) and was originally in the Atkinson collection but is now, I believe, in the Berlin Museum.

Grünberg [31] comments on *Lophopteryx saturata* Walker as follows:

L. saturata *Walk.* (46h). A North Indian species closely related to *camelina*, and lately also found in Japan. Forewing dark red brown with a grey tone and sharp black pre- and postdiscal bands. Hindwing greyish brown, the black anal spot bounded by a sharp whitish transverse line.

In the southern Ussuri-district the species is represented by a special form, hoegei *Graes.*, which differs from the closely allied *camelina* and *giraffina* in the colouring being darker, more brown-grey, and in the black markings being more sharply developed; moreover, the outer edge of the median band is less sharply dentate, more straight, the lobe of scales at the hind margin paler than the ground.

Graeser [32] says of *Lophopteryx hoegei* Graeser:

I reared seven ♂♂ and three ♀♀ of this new species at Wlad. [Wladi-wostock]. It comes near to *Camelina*, and reminds one on superficial obser-vation of dark specimens of ab. *Giraffina* Hb. Herr Cristoph, to whom I sent one of my specimens, also identified it as an exceptionally sharply defined and aberrant specimen of *Giraffina*, which however is, at once con-tradicted by the quite different larva which is described further on.

Hoegei has the expanse of a middle-sized *Camelina;* male expanse 32–34 m. m.; female expanse 36–39 m. m. The fore wings are not so much ex-curved at the anterior angle as in *Camelina*, but the costal margin is here somewhat shortened, the hind margins of the wings are less sharply dentate at the nervures, the hind wing, in particular, is not conspicuously dentate at the anal angle, but runs here almost straight, scarcely perceptibly ex-curved. The whole insect is darker and more brownish-grey than *Camelina* and *Giraffina*. The ground colour of the fore wings is a dark brownish-grey, that of the hind wings a dull smoky-grey ["trüb rauchgrau"]; *Hoegei* never has rust-brown fore- and brownish-yellow hind wings like *Camelina* in which also the hind wings are always much lighter coloured than the fore wings. All markings agree in their arrangement tolerably well with those of *Camelina*, they are however more delicate and in all ten specimens are more sharply defined than in the former, which sometimes appears quite devoid of markings. In the fore wing of *Hoegei* the outer edge of the me-dian band is very sharply defined; it consists of a slender black line and of a broader greyish-yellow line lying parallel with it and runs much straighter, not so sharply dentate as in *Camelina*, moreover the two pointed spurs directed inwards between veins 4 to 6 are also missing, it runs here in a gentle arch which is scarcely dentate. The fringes of the outer margin are somewhat lighter from the hinder angle to vein 4, from there to the anterior angle just as dark as the wing. The lobe of scales of the inner margin is in *Hoegei* somewhat paler than the ground colour, whereas in *Camelina* it is constantly of a darker shade. On the outer margin of the hind wings there

[31] Seitz's Macrolep. Faun. Pal. 2 (1912) 307.
[32] Berl. ent. Zeit. (1888) 144, No. 376.

is a thin pale terminal line before the darker fringes; between the anal angle and vein 2 there is a small mark; this consists of a pale yellow transverse streak, bordered on each side by black; bordering this there is a patch of blue-grey scales. The underside of all wings is an uniform smoky-grey, the anterior margin is quite narrowly suffused with yellow near the anterior angle, the fringes of all wings somewhat darker than these even.

The thorax is crested and hairy, also the patagia, and it is coloured grey brown tinged with lighter; the body smoky grey on both sides; antennæ dark brown, the same as in *Camelina;* the palpi, which project but little, dark brown as well as the whole head, between the antennæ blackish; pectus and legs very hairy, dark brown; feet ringed with paler colour; hind tibiæ have two pairs of spurs.

My artist's original figure of the larva figured (Plate 2, fig. 6) of *Lophopteryx saturata* Walker agrees well with Graeser's description of the larva of *Lophopteryx hoegei* Graeser which I have translated as follows:

Full grown larva, length 50 millimeters; very slender, pale yellow, the glossy black head is globular, the first segment behind that swollen like a blister, the upper half reddish-yellow; from the second to the eleventh segment run seven thick black longitudinal lines, one of which is medio-dorsal and another just over the black spiracles; segment 11 with a prominence which bears two obtuse brick-red tubercles situated close together which are joined by the black longitudinal lines; the dorsal area behind these tubercles is sprinkled with irregular black spots and points; an oval black spot on the anal flap. Laterally a broad sulphur yellow longitudinal stripe from head to anus; the body black below this stripe; a narrow pale yellow stripe on the ventrum which is somewhat widened at each pair of feet. Thoracic legs yellow with black claws, abdominal legs black with slender yellow rings. The whole larva shines like lacquer, naked with quite isolated, fine hairs.

In two broods, gregarious on maple in August. A brood of 30 full grown larvæ were found on a maple tree on 2 August, which pupated a few days later, the imagoes emerging on 22 August. Some of these were allowed to breed, the larvæ emerged from the blue-green ova on 4 September and pupated at the commencement of October; about 130 pupæ which were obtained from these went to earth during the journey.

I may mention here that the larva of the very closely allied species *Lophopteryx camelina* Linnæus which is recorded from Japan, is so different in color that it seems worth while quoting Wilson's [33] description of that larva as follows:

Larva [of *Notodonta camelina* Linnæus]. Bright green, much lighter on the dorsal area, with some scattered white warts; dorsal line blue-green, passing between two red humps on the 12th segment, these red humps have each a tuft of black hairs; spiracular line yellow; spiracles black, encircled with white; and beside each is a pink blotch; segmental divisions yellow;

[33] Larvæ of British Lepidoptera (1880) 195, pl. 30, figs. 1, 1a.

there are a few black dots and some black hairs on the body; ventral area green; head yellow-green and shining, yellower towards the mouth; legs and claspers pink. In some varieties the ground color is yellowish buff. The larva rests with the 13th segment raised, and its head curved back over the body. *Plate XXX, figs. 1, 1a.*

Eggs laid on the 16th of July, hatched on the 24th of the same month. When first hatched, the larva is whitish, the head black, large, and shining.

Food plants. Apple, Alder, Birch, Beech, Elm, Hazel, Lime, Maple, Oak, Sallow, Whitethorn, Willow.

Pupa. In a slight cocoon under moss on trees.

Time of appearance.—*Larva.* July to October. Pupa. *October to May. Imago.* May to September.

Localities. Great Britain and Ireland; common.

Imago.—Staudinger [34] remarks:

Graeser described his *Hoegei* from 10 specimens reared at Wlad. [Wladiwostock], the larvæ of which lived on oak [35] and which were very different from those of *Camelina.*

According to his description in which however the transverse lines do not agree, being quite different, *hoegei* is the same species as specimens from Ask. [Askold], which Oberthür quotes,[36] as *saturata* Moore from an Askold male, and of which I have two males from Askold from Dörries. *Lophopteryx saturata* from Sikkim was not described by Moore, but by Walker, and 4 males from Darjiling, which lie before me, agree so well with my two Askold specimens that the latter can, in any case, only be a very slightly varying local form of it. Moreover *saturata* are somewhat browner, darker brown on the fore wings, and the hind wings also are a dark brownish gray, not "trüb rauchgrau" [dull smoky grey], as Graeser calls it. They are also lighter on the underside than those of *saturata.*

Local distribution.—Honshu, Shinano Province, Karuizawa, July (near typical *Lophopteryx saturata* male) (*Wileman*). Hokkaido, Oshima Province, Tobetsu, Junsai Numa, and Hakodate, June, July, August, September (bred August, September) (*Wileman*) : Ishikari Province, Sapporo, August (*Wileman*). Matsumura does not record *Lophopteryx saturata* from Japan but records the very closely allied species *Lophopteryx camelina* Linnæus from Hokkaido and Honshu.

[34] Rom. Mém. Lép. 6 (1892) 360.

[35] Graeser says "Ahorn gebüsch" [Maple], not "Eiche" [Oak] as Staudinger states, and my larvæ were also found on maple. I have given this species the Japanese name of *momiji-shachihoko* for this reason.

[36] Etudes 5: 66.

Time of appearance.—Larva, July, August, October; imago, June to September. A pupa bred from an October larva hibernated and emerged in June of the following year, so that the hibernating pupæ apparently produce the imagoes which appear in June and there may be two broods in the year.

General. distribution.—*Lophopteryx saturata* Moore, India (Sikkim), Japan (*Wileman*). *Lophopteryx hoegei* Graeser, East Siberia (Ussuri) ; Japan (*Wileman*).

Genus **EUHAMPSONIA** Dyar

Euhampsonia DYAR, Trans. Am. Ent. Soc. 24 (1897) 14.

Euhampsonia cristata Butler.

> Plate 2, fig. 9, larva; fig. 10, food plant; fig. 11, head.
> Japanese name, *sedaka-shachihoko.*
> *Trabala cristata* BUTLER, Ann. & Mag. Nat. Hist. IV 20 (1877) 480;
> Ill. Typ. Lep. Het. 2 (1878) 18, pl. 27, fig. 1, ♀; PRYER, Trans.
> Asiat. Soc. Japan 12 (1883) 55, No. 217; LEECH, Proc. Zool. Soc.
> London (1888) 628, No. 233; GRAESER, Berl. ent. Zeit. 32 (1888)
> 142 (larva); KIRBY, Cat. Lep. Het. (1892) 614; STAUDINGER, Rom.
> Mém. Lép. 6 (1892) 367; LEECH, Trans. Ent. Soc. London (1898)
> 297, No. 93; STAUDINGER and REBEL, Cat. Lep. Pal. 1 (1901) 111,
> No. 855; MATSUMURA, Cat. Insect. Jap. 1 (1905) 38, No. 313;
> Thousand Insects of Japan [Zoku Nihon Senchū Dzukai (Jap.)]
> (1909) Suppl. 1, 45, No. 73, pl. 7, fig. 4, ♀; GRÜNBERG, Seitz's
> Macrolep. Faun. Pal. 2 (1912) 310, pl. 47*b*, ♂, ♀; MATSUMURA Ōyō
> Konchūgaku (Practical Entomology) ed. 2. (1920) 712 (Jap.).
> *Euhampsonia cristata* MARUMO, Journ. Coll. Agr. Imp. Univ. Tokyo
> 6 (1920) No. 4, 329, No. 78, pl. 22, fig. 3, ♂; pl. 31, fig. 6; pl. 35,
> fig. 1; text fig. 30.

The larva figured (Plate 2, fig. 9) was taken in September, 1902 (figured, September 21), at Hakodate, Oshima Province, Hokkaido, on dwarf oak, Japanese name, *ko-nara* (*Quercus glandulifera* Blume). This larva died without developing an imago, but I have bred imagoes on several occasions at Tokyo, Honshu, from similar larvæ taken on oak. It is quite impossible to mistake it for the larva of any other Japanese cerurid (notodont).

Graeser [37] describes the larva of *Nadata* [=*Euhampsonia*] *cristata* Butler as follows:

> I found the full grown larvæ not rare in the second half of August on oak. It is naked, of a whitish green ground color and has laterally on each segment bright yellow oblique stripes; head very large, globular, whitish green; the pupa hibernates.

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[37] Berl. ent. Zeit. 32 (1888) 142.

Matsumura [38] states that *Euhampsonia splendida* Oberthür—

male, is not rare at the end of July in Sapporo [Hokkaido]. I have never yet taken a female. I think that it perhaps may be the male of the Sedaka-shachihoko [*Euhampsonia cristata* Butler].

Judging by the following facts, however, it is evident that *cristata* Butler and *splendida* Oberthür are two quite distinct species with different larvæ and that the females of each are distinct and well known.

1. The male antennæ of *cristata* Butler are bipectinate for the proximal three-fourths length of the shaft and the pectinations are nearly one-third longer than in male *splendida* Oberthür. The antennæ of *splendida* Oberthür are bipectinate for the proximal five-eighths length of the shaft and the pectinations are slenderer and shorter than those of *cristata* Butler.

2. Graeser [39] states of *Nadata splendida* Oberthür:

I bred 4 ♂ and a ♀ from the larvæ. I found these full grown from 23 August to 3 September on oaks where they generally rest on the underside of a leaf which has been spun over with thin white threads. The large larva 70–80 m. m. long is of an uniform greenish white, the large globular head also is of this colour. The pupa hibernates.

In the previous number, on the same page (142), Graeser has already described the larva of *Nadata cristata* Butler and in the next number he describes the larva of *Nadata splendida* Oberthür. It is very evident therefore that he bred the larvæ of both species and he specially mentions that he bred a female of *splendida* Oberthür from the larva. Staudinger [40] also says of *Nadata (Euhampsonia) splendida* that "Christoph found (bred) a ♀ end of June, a ♂ end of July at Wlad. [Wladiwostock]," so that there seems no doubt that *Euhampsonia splendida* has a well-defined distinct female, but it seems to be, for some reason, very scarce. The larva of *E. splendida* Oberthür lacks the bright yellow oblique stripes of *cristata* Butler which however are white in my Japanese figure of *cristata*.

I describe the larva from my artist's original figure as follows:

Larva.—Length, about 52 millimeters. Head light green and mandibles tinged with pink; naked, glossy; dorsally whitish green; laterally and ventrally of a darker green; seven white

[38] Thousand Insects of Japan [Shin Nihon Senchū Dzukai (Jap.)], Additamenta 4 (1921) 815, No. 815, pl. 59, fig. 13, ♂.

[39] Berl. ent. Zeit. 32 (1888) 142.

[40] Rom. Mém. Lép. 6 (1892) 366.

lateral stripes commencing on segment 5 directed toward the
anus obliquely upward and backward; legs ochraceous; prolegs
and claspers green; anal flap edged with yellow.　It will be noted
that Graeser describes the lateral stripes as yellow, but all the
larvæ of this species observed by me were marked with white
stripes.　I have also sometimes found it feeding on *akebi* (*Akebia quinata* Decaisne).

Pryer remarks that "the larva of this fine Notodonta closely
resembles that of a Smerinthus."

Local distribution.—Honshu, Musashi Province, Yokohama
(*Jonas, Pryer*) : Shinano Province, Oiwake (*Pryer*) : Omi Province, Nagahama, July (*Leech*) : Yamato Province, Yoshino, July,
August (*Wileman*) : Musashi Province, Tokyo, June (bred),
July (*Wileman*) : Sagami Province, Onuma, July (*Wileman*).
Hokkaido, Oshima Province, Hakodate (larva), September
(*Wileman*).　Matsumura records this species from Hokkaido
and Honshu.

Time of appearance.—Larva, September; imago, June to
August.　Hibernates in the pupal stage.

General distribution.—Eastern Siberia, southern Amurland;
North China; Japan (*Grünberg*).　Manchuria (*Matsumura*).
Type, female, from Yokohama (*Jonas*).

Genus ICHTHYURA Hübner

Ichthyura Hübner, Verz. bek. (1822) 162.

Ichthyura anachoreta Fabricius.

Plate 1, fig. 13, larva; fig. 14, food plant.
Japanese name, *tsumaaka-shachihoko*.

Bombyx anachoreta Fabricius, Mant. Ins. 2 (1787) 120 (= *curtula*
Esper; *fulgurita* Walker); Hübner, Bomb. (1880) pl. 22, fig. 88;
Leech, Proc. Zool. Soc. London (1888) 636, No. 261; Staudinger,
Rom. Mém. Lép. 6 (1892) 373; Hampson, Moths Brit. India 1
(1892) 172, larva; Leech, Trans. Ent. Soc. London (1898) 317,
No. 156; Staudinger and Rebel, Cat. Lep. Pal. 1 (1901) 112, No.
.869; Matsumura, Cat. Insect. Jap. 1 (1905) 39, No. 321; Thousand
Insects of Japan [Zoku Nihon Senchū Dzukai (Jap.)] (1909)
Suppl. 1, 53, No. 87, pl. 9, fig. 6, ♂; Nagano, Nawa's Insect World
[Konchu Sekai (Jap.)] 13 (1909) 445, pl. 21, fig. 3, ♂; fig. 4,
♀; fig. 16, larva; fig. 18, pupa; fig. 17, cocoon; Sasaki, Nihon
Jūmoku Gaichūhen (Insects Injurious to Japanese Trees) ed. 3
(1910) pt. 2, 161, text-fig. 150, larva, imago ♂; Grünberg, Seitz's
Macrolep. Faun. Pal. 2 (1912) 314, pl. 47g, ♂; Nagano, Bull.
Nawa Ent. Lab. 1 (1916) 9, pl. 3, figs. 11–20, pl. 9, fig. 23, larva;
Marumo, Journ. Coll. Agr. Imp. Univ. Tokyo 6 (1920) No. 4,
333, No. 84, pl. 29, fig. 12; pl. 38, fig. 6; Matsumura, Ōyō Konchugaku [Practical Entomology] ed. 2 (1920) 714, (Jap.).

Ichthyura fulgurita WALKER, Cat. Lep. Het. **32** (1865) 433; KIRBY, Cat. Lep. Het. (1892) 611.

Nerice pallida WALKER, Cat. Lep. Het. **5** (1855) 1087; STAUDINGER, Stett. ent. Zeit. (1887) 101; GRÜNBERG, Seitz's Macrolep Faun. Pal. **2** (1912) 315.

The larva figured (Plate 1, fig. 13) was taken in November, 1900 (figured, November 6) at Kobe, Settsu Province, Honshu, on a species of sallow, Japanese name, *yanagi* [41] and a male imago emerged from the pupa on April 20, 1901. Hampson [42] describes the larva as follows:

Larva pale brown, covered sparsely with short pale hair; a dorsal hump on 4th somite, with paired white spots on each side of it, an indistinct dark dorsal line; lateral area streaked with dark brown.

Wilson [43] describes the larva as follows:

Larva. Long and somewhat slender; segmental divisions distinctly marked; head black, shining, and bifid; 2nd segment large and swollen. Very dark brown, with four ochreous lines down the back, commencing at the 3rd segment; on each side of this series of lines on each segment, is an orange-coloured wart, from which proceed a number of long light hairs; there is also a row of these warts along each side above the spiracles, and below them a number of markings of the same colour; on the 5th segment is a black and shining hump *with a bright white mark on either side of it;* on the 12th segment is a smaller hump of a similar character, with a transverse orange line behind it; spiracles brown encircled with pale buff, legs and claspers behind. *Plate XXIX, fig. 4.*

Food-plants. Poplar, sallow.

Pupa. Amongst the leaves of the food-plant.

Time of appearance. *Larva.* July to October. *Pupa.* October to May. *Imago.* August to May.

(Great Britain, Wilson.)

Grünberg [44] describes the egg and larva as follows:

Egg lentiform, brown-grey with brown transverse band.

Larva reddish grey with grey yellow hair, dark dorsal line and large, interrupted black dorsolateral spots. The tubercle on abdominal segment 1 moderately high, that on segment 8 smaller, brown-red bordered with black, the former accompanied by a prominent white spot. The small orange-red lateral warts weak as in *P. curtula* with which the larva agrees in habits. Pupa rather slender, glossy black-brown, with the segmental incisions of the abdomen red-brown, the apex as in *P. anastomosis.* Cocoon loose, brownish-grey between leaves.

[41] "Yanagi" is apparently used for either sallow or willow in Japanese.
[42] Moths British India 1 (1892) 173.
[43] Larvæ of British Lepidoptera (1880) 193, pl. 29, fig. 4.
[44] Seitz's Macrolep. Faun. Pal. 2 (1912) 315.

My larva agrees well with the preceding description with the exception that the lateral area is strongly marked with a dark, blackish-brown, supraspiracular, longitudinal stripe which appears in my artist's original figure to be continuous and not interrupted.

Sasaki [45] records the life history of *Clostera* [=*Ichthyura*] *anachoreta* Fab. and gives figures and descriptions of the imago and larva. He says that—

The larva appears in May and feeds on *Yanagi* (Sallow).[46] It is full grown at the commencement of June, and the imago emerges at the end of June.

Nagano [47] records the life history of *Pygaera* [=*Ichthyura*] *anachoreta* Fabricius and gives figures and descriptions of the larva, pupa, cocoon, and imago, male and female. He deduces the following facts from the dates of appearance of the larva and imago of the species.

The imago of the hibernated pupa emerges in April or May of the following year, and oviposits on the trunks of yanagi (sallow or willow). The first brood of larvæ resulting from these ova probably develops the first brood of imagoes in June, July, and August which oviposit a second time, producing a second brood of larvæ, but whether this second brood of larvæ develops the first brood of imagoes next year is not clearly proved. At the end of October, however, full-grown larvæ are to be discovered on the sallow leaves; and it, therefore, seems clear that the species must hibernate in the pupal stage. During this month no cocoons are to be found spun on the sallow twigs as the larvæ appear to spin their cocoons among the withered leaves on the surface of the ground. However this may be, it is evident that the imago of this species seems to have no clearly defined period of emergence, and further investigations are necessary to prove whether there are two or three broods.

Matsumura [48] gives the following trees, in addition to those already mentioned, as food trees of *Pygaera* [=*Ichthyura*] *anachoreta* Fabricius. *Yamanarashi* [Aspen, *Populus tremula*

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[45] Nihon Jūmoku Gaichūhen [Insects Injurious to Japanese Trees (Jap.)] ed. 3, pt. 2, 161, pl. 150, larva, imago, ♂.

[46] The name for sallow and willow appears to be the same in Japanese, namely Yanagi.—A. E. W.

[47] Nawa's Insect World (Konchū Sekai) **13** (1909) 445, pl. 21.

[48] Ōyō Konchūgaku (Practical Entomology) ed. 2 (1920) 714 (Jap.).

Linnæus var. *villosa* Wesm.]; *hakuyō* [White poplar, *Populus alba* Linnæus].

Local distribution.—Honshu, Musashi Province, Tokyo, April, (*Wileman*), Yokohama (*Marumo*): Yamato Province, Yoshino, July, September, October (*Wileman*): Kii Province (*Marumo*): Mino Province, Gifu (*Nagano*): Settsu Province, Kobe, April (bred) (*Wileman*). Hokkaido, Oshima Province, Hakodate, June (*Wileman*). Matsumura records this species from Honshu and Hokkaido and Nagano records it from Shikoku and Kyūshū.

Time of appearance.—Larva, April, October, November; imago, April, June, July, September, October. There are probably two or three broods of the imago in the year according to locality and latitude.

Matsumura[49] states that "in Tokyo [Honshu] there are two broods; in Hokkaido there is one brood and in Kyūshū there are three broods."

As Hokkaido is the most northern of these three islands and Kyūshū the most southern, Honshu lying between them, there is approximately a range of over 10° of latitude between these first two islands and therefore a great variation in temperature which would account for the difference in the number of broods.

General distribution.—*Ichthyura anachoreta* Fabricius. From northern Europe, with the exception of the higher latitudes, to northern Italy and northern Spain, southern Russia, Armenia, eastern Asia, China, Japan, India. In central Europe everywhere, but rarer than *curtula* and *anastomosis*, likewise in two broods, April-May and July-August; in the North one brood, May-June. Also in this species (*Pygaera anachoreta* Fabricius) a paler variety, *pallida* Walk., has been separated, which extends from central and eastern Asia into the Oriental Region (*Grünberg*), Manchuria (*Matsumura*), Siberia and Corea (*Marumo*).

ERRATA IN NOTES ON JAPANESE LEPIDOPTERA, PARTS IV, V, AND VI

Philippine Journal of Science 12 § D (1917) No. 4:
    Page 230, line 19, *for* Arctiidæ *read* Arctiadæ.
    Page 231, line 30, *for* Arctiidæ *read* Arctiadæ.
    Page 231, line 31, *for* Lithosiinæ *read* Lithosianæ.
    Page 234, line 28, *for* Arctiidæ *read* Arctiadæ.
    Page 234, line 29, *for* Arctiinæ *read* Arctianæ.
    Page 234, line 40, *for* (1105) *read* (1905).

[49] Loc. cit.

Philippine Journal of Science 12 § D (1917) No. 4—Continued.
    Page 235, line 30, *for* Diarcrisia *read* Diacrisia.
    Page 238, line 1, *for* Arctiids *read* Arctids.
    Page 239, line 1, *for* Leach *read* Leech.
    Page 241, line 4, *for* is *read* it.
    Page 242, line 33, *for* opulanta *read* opulenta.
    Page 244, line 15, *for* Greaser *read* Graeser.
    Page 244, line 17, *for* Kashomir *read* Kashmir.
    Page 244, line 29, *for* Shikubi *read* Shiokubi.
    Page 245, line 15, *for* ocharcea *read* ochracea.

Philippine Journal of Science 13 § D (1918) No. 4:
    Page 151, line 7, *for* Lymantriidæ *read* Lymantriadæ.
    Page 152, line 7, *for* Ochisenheimer *read* Ochsenheimer.
    Page 154, line 17, *for* Higoshi-no-kawa *read* Higashi-no-kawa.
    Page 155, line 17, *for* description *read* figure.
    Page 155, line 42, *for* Konshū *read* Konchū.
    Page 157, line 13, *for* Jumaku *read* Jumoku.
    Page 158, line 42, *for* Jumuku *read* Jumoku.
    Page 161, line 10, *for* lymantriid *read* lymantrid.
    Page 162, line 6, *for* Lymantriidæ *read* Lymantriadæ.
    Page 162, line 8, *for* lymantriid *read* lymantrid.
    Page 163, line 9, *for* Phal. *read* Pal.
    Page 164, line 43, *for* Larvae *read* Larvæ.
    Page 165, line 17, *for* Bull. l'Acad *read* Bull. de l'Acad.
    Page 167, line 8, *for* "on *read* on.
    Page 167, line 15, *for* hairs." *read* hairs.
    Page 168, line 8, *for* Apaha *read* Apha.

Philippine Journal of Science 19 (1921) No. 2:
    Page 209, *after* line 8 *read* Samia Hübner.
    Page 211, line 20, *for* konzui *read* gonzui.
    Page 211, line 20, *for* [Latin name unknown, not given by Matsumura
        in his Shokubutsu Mei-i]. *read* (*Euscaphis japonica* Pax).
    Page 216, line 15, *for* hime-yama-nai *read* hime-yamamai.
    Page 218, line 36, *for* japoncia *read* japonica.
    Page 219, line 25, *for* Dzukei *read* Dzukai.
    Page 219, line 27, *for* Jumuko *read* Jumoku.
    Page 220, line 36, *for* Ku-su-no-ki *read* Kusunoki.
    Page 220, line 39, *for* Populas *read* Populus.
    Page 221, line 32, for [*keyaki* read *keyaki* and for (*Zelkowa acuminata*
        Pl.)] read [*Zelkowa acuminata* Planchon].
    Page 221, line 37, *for* He says that *read* He says that:
    Page 221, line 38, *for* "in *read* "In.
    Page 221, line 39, delete quotation marks.
    Page 222, line 13 *for* sale. *read* sale."
    Page 223, line 1, *for* Yō hō *read* Yōhō.
    Page 224, line 36, *for* Jansai *read* Junsai.
    Page 227, line 31, *for* nedzumu-mochi *read* nedzumi-mochi.
    Page 228, line 19, *for* wich *read* which.
    Page 228, line 21, *for* stmes *read* stems.

ILLUSTRATIONS

[Drawings by Hisashi Kaidô.]

PLATE 1

FIGS. 1 and 2. *Fentonia ocypete* Bremer forma *japonica* Grünberg. *1*, larva; *2*, food plant.
3 and 4. *Cerura milhauseri* Fabricius. *3*, larva; *4*, food plant.
5 to 7. *Lophocosma atriplaga* Staudinger. *5*, larva; *6*, food plant; *7*, head.
8 and 9. *Brachionycoides atrovittatum* Bremer. *8*, larva; *9*, food plant.
10 to 12. *Hyperæschra biloba* Oberthür. *10*, larva; *11*, head; *12*, food plant.
13 and 14. *Ichthyura anachoreta* Fabricius. *13*, larva; *14*, food plant.

PLATE 2

FIGS. 1 and 2. *Drymonia lineata* Oberthür. *1*, larva; *2*, food plant.
3 to 5. *Spatalia macrodonta* Butler. *3*, larva, green form; *4*, larva, violet-gray form; *5*, food plant; *5a*, imago, ♂.
6 to 8. *Lophopteryx saturata* Walker. *6*, larva; *7*, food plant; *8*, anal section, dorsal aspect.
9 to 11. *Euhampsonia cristata* Butler. *9*, larva; *10*, food plant; *11*, head.

109

PLATE 1. JAPANESE LEPIDOPTERA.

PLATE 2. JAPANESE LEPIDOPTERA.